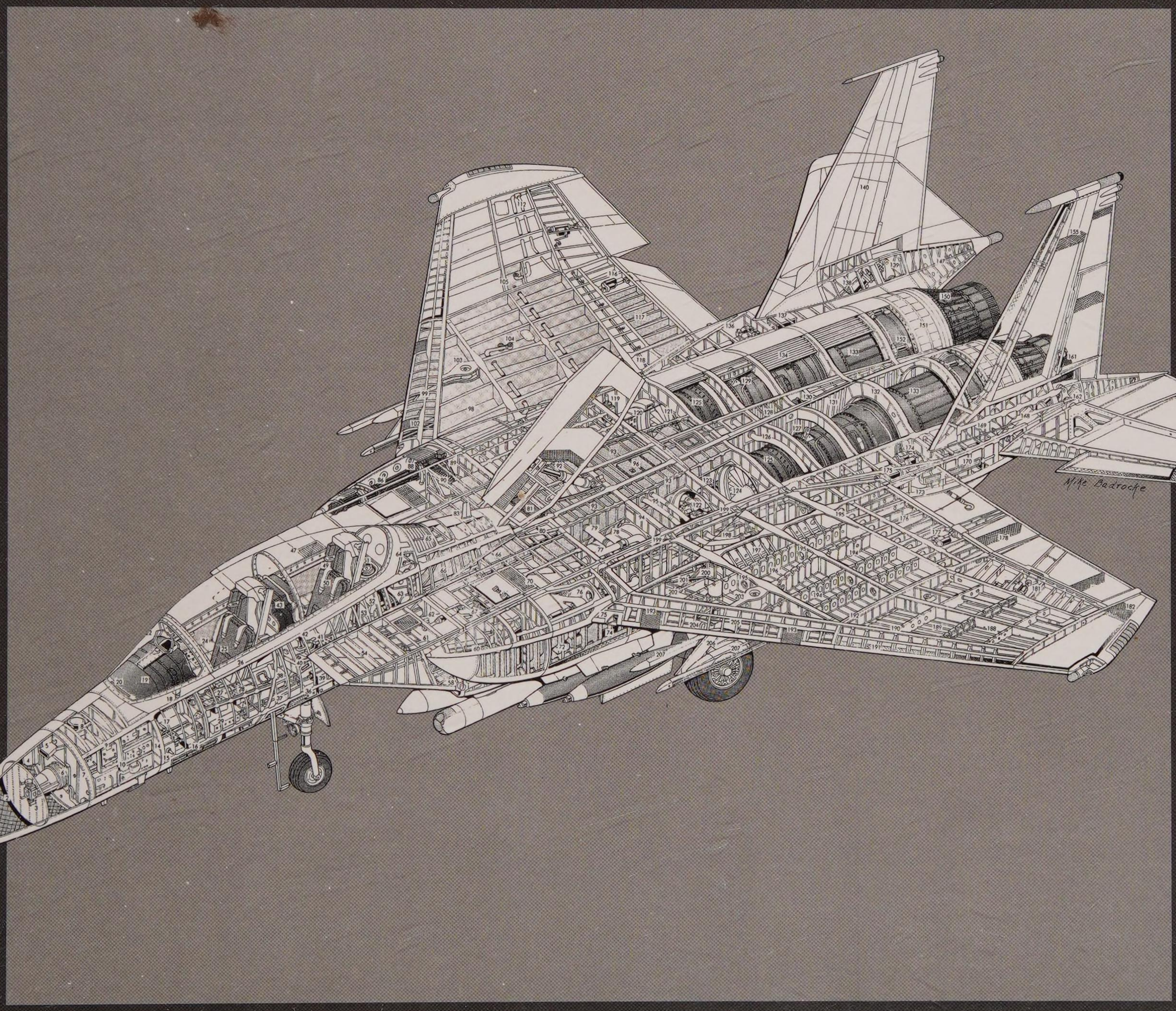
McDONNELL DOUGLAS/BOEING

# F-15 EAGLE

## 1972 onwards (all marks)

# Owners' Workshop Manual




An insight into operating, flying and maintaining the USAF's all-weather tactical jet fighter

**COVER CUTAWAY: F-15E Strike Eagle.** *(Mike Badrocke)*


## Acknowledgements

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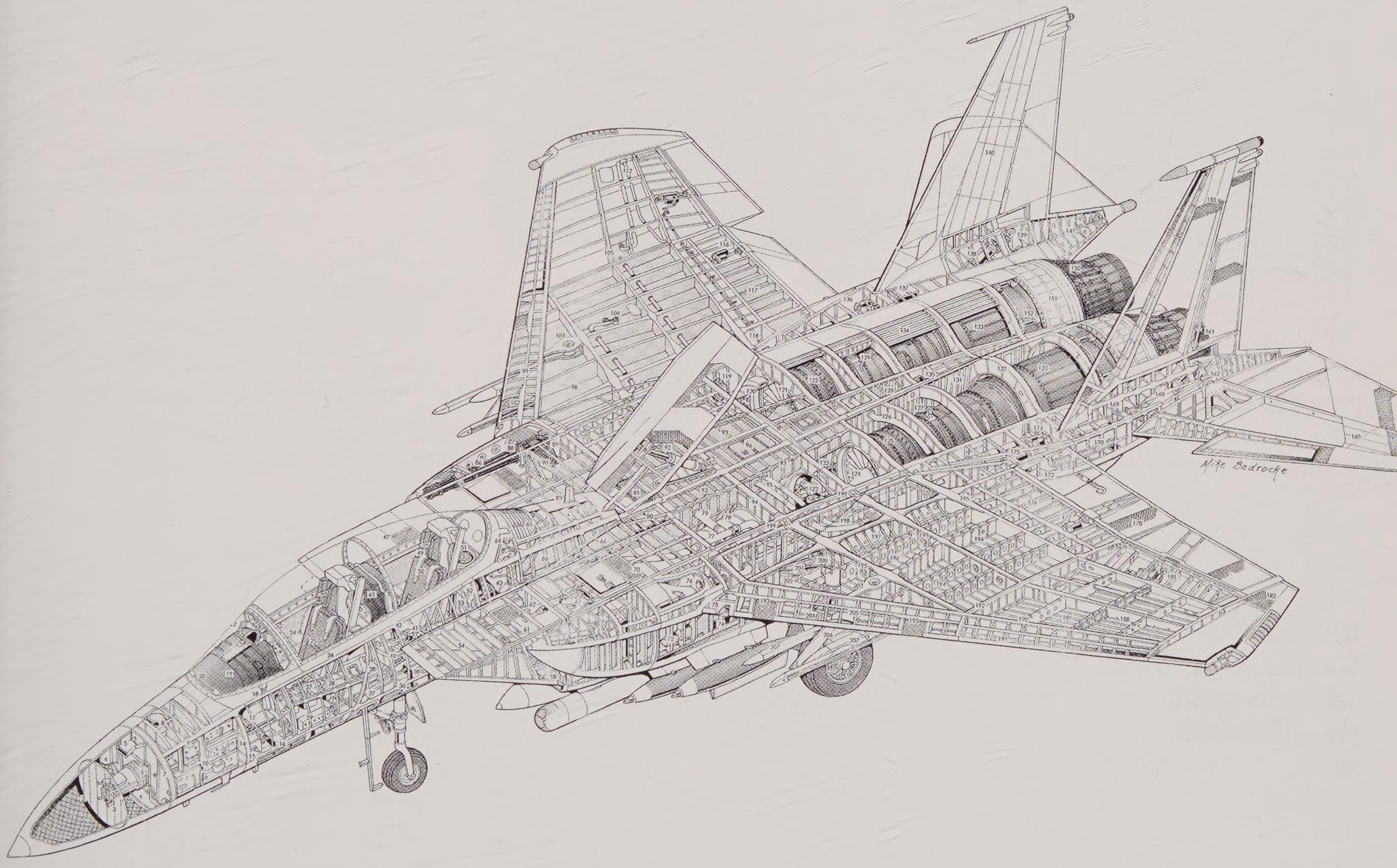
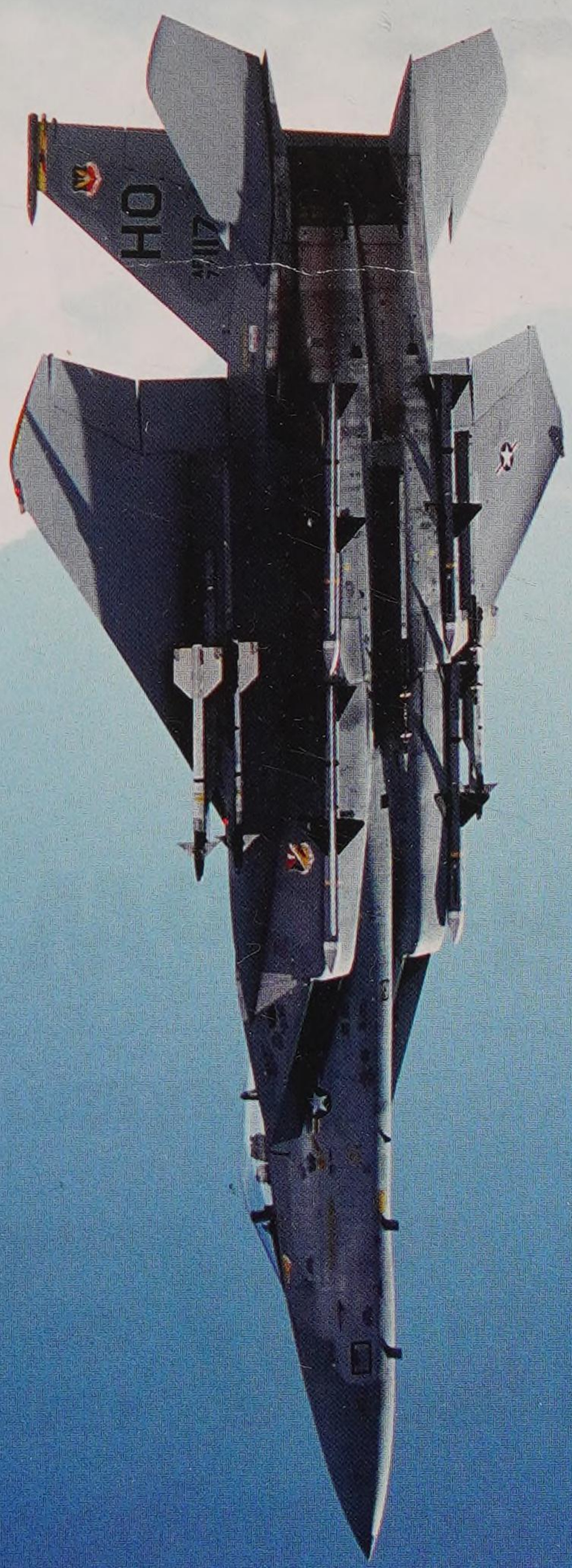



An insight into operating, flying and maintaining the USAF's all-weather tactical jet fighter

**Steve Davies and Doug Dildy**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**OPPOSITE** **The zoom climb, though perhaps not quite as spectacular as this Holloman Air Force Base F-15A would have you think, was the best way to intercept high- and fast-flying Soviet interceptors, usually with a volley of AIM-7s. The white AIM-9s are left over from the days when the F-4's belly was painted the same colour. Like the grey AIM-7s seen here, the Sidewinders would also eventually be painted grey to better blend in with the Eagle. Aircraft 77-117 was an 8th TFS 'Black Sheep' jet. It was passed to the 122nd FS, Louisiana ANG, in September 1991. It crashed on 12 June 1993, 30 miles east of New Orleans. Its pilot ejected safely.** *(USAF)*

BOAR LEAD
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390FS
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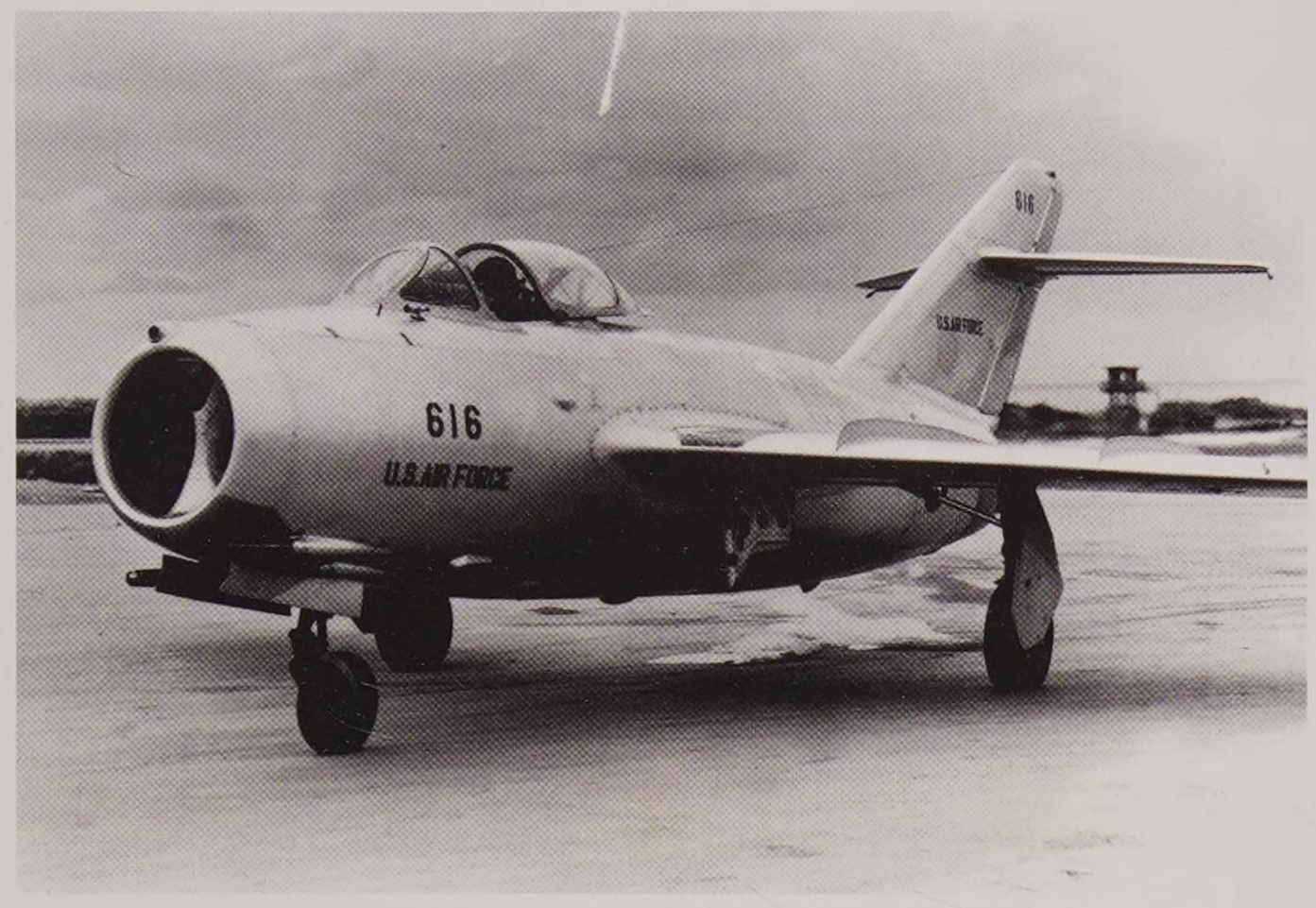
*Chapter One*

# The Eagle story

**The Boeing (formerly McDonnell Douglas) F-15 is statistically the most successful fighter jet ever built, with 105 kills for zero losses. Big and fast, with a very useful combat range, the aircraft is also undeniably beautiful.**

**OPPOSITE A 'Wild Boar' F-15C of the 390th FS, 336th Wing, Mountain Home AFB, carrying an AIM-120 telemetry round with a live motor. As this portrait shows, the Eagle is an undeniably good-looking fighter.** *(USAF)*




**ABOVE The MiG-15 – the first captured example is seen here wearing US Air Force markings – was typical of Russian-designed and Soviet-built jet fighters: ruggedly built, simple to operate and maintain, and reliable. It was also highly manoeuvrable.** *(USAF)*

There are two distinct versions of the F-15 in operation with air forces around the world in 2014: the F-15A/B/C/D 'light grey' Eagle air supremacy fighter, and the F-15E Strike Eagle 'dark grey' multi-role fighter. This book will focus primarily on the F-15C/D and F-15E in operation with the United States Air Force (USAF).

Despite the USAF focus of this book, the reader should know that the Eagle and Strike Eagle (and derivatives of the latter) are also operated by international users – the air forces of Israel, Saudi Arabia, Japan, Singapore and South Korea. While in the hands of the Israelis in particular the Eagle and Strike Eagle have performed with alacrity – the author leaves it to others to tell those stories.

## Lessons written in blood

On 25 June 1950, Communist North Korea invaded South Korea. The Korean War was the first occasion on which US-built jet fighters engaged in combat against those built by the Union of Soviet Socialist Republics (USSR). The North American F-86 Sabre – fast, manoeuvrable and well armed – was pitted against the Mikoyan-Gurevich (MiG) design bureau's more numerous MiG-15.

The MiG-15 was simple, but it was also rugged and manoeuvrable. Built on the principle of what an American fighter pilot once jokingly summarised as 'building airplanes that an uneducated farm hand could hop in and fly', it was straightforward to operate and cheap to replace.

When the war ended, the USAF's kill ratio stood at a respectable 7:1. Many of the Sabre pilots had gone to Korea with combat experience aplenty – they had only five years' before been flying propeller-driven fighters against the Axis forces in World War Two. In the intervening time, little about air combat had changed except the method of propulsion and the speeds involved. To shoot down an adversary, you still had to close to within gun range.

But in the United States the advent of missile technology and the focus on nuclear capabilities meant that a shift in air combat thinking was taking place, driven mostly by Strategic Air Command (SAC). The dominant

**RIGHT Following on the heels of World War Two, the F-86 was not dissimilar to the MiG-15 in its simplicity of design and operation. However, it would be one of the United States' last such designs. While the Soviets retained the core principles of simplicity with the MiG-17, MiG-19 and MiG-21, America was developing ever more complex designs.** *(USAF)*

major command in the United States Air Force, SAC was responsible for nuclear strikes. It was so powerful that it was even going as far as stipulating the design considerations of tactical fighters – assets that it did not even own.

SAC decreed that the Air Force should purchase fighters that could deliver atom bombs or defend against delivery of the same. From that stipulation came the Century fighters series (F-100 through F-106), with the Convair F-106 becoming the ultimate air defence interceptor, and the Republic F-105 the primary nuclear delivery fighter-bomber.

Meanwhile, with the arrival of the Kennedy Administration's Robert S. McNamara as head of the Department of Defense (DoD) there came a forced uniformity between the US Navy (USN) and the USAF. This had many consequences, of which the adoption of the Navy's McDonnell F-4 Phantom II as the Air Force's follow-on tactical fighter was one. The Phantom had first flown for the USN in May 1958, and was designed primarily as a fleet defence fighter, with a secondary ground attack capability. Consequently it had a superior Westinghouse APQ-72 radar operated by a second crew member, freeing the pilot to fly the aircraft. It was armed with four semi-active radar (SAR) homing AIM-7 Sparrows and four heat-seeking AIM-9 Sidewinders, both of which were superior to the USAF's AIM-4 Falcon, which came in both varieties. Plus, it could carry 11,000lb of air-to-ground ordnance.

But it was optimised for fleet defence, meaning that it was specifically designed to shoot down Soviet Naval Aviation Tu-20/95 'Bear' (fielded in 1955) and Tu-16 'Badger' (1961) bombers attempting to launch AS-1 'Kelt' and AS-3 'Kangaroo' stand-off missiles against the USN's carrier battle groups. For this role the gun – that legendary, simple and reliable weapon of the traditional fighter aircraft – was superfluous to requirements.

The Phantom II proved to be a powerful and effective tactical performer, shooting down 107 MiGs in the skies of North Vietnam (NVN), carrying the brunt of the air offensive into NVN during operations Linebacker I and Linebacker II that ended the war, and conducting

**ABOVE The Phantom's APQ-72 radar offered acceptable performance in the look-up environment, but when looking down would be blinded by ground clutter. The radar was ideal for the role for which it was designed (targeting high-altitude nuclear bombers), but was inadequate for detecting small, nimble MiGs in low-altitude orbits.** *(USAF)*

**LEFT Slats on the F-4E's leading edges improved its low-speed performance and made it a more capable dogfighter. With its built-in M61A1 gun below the nose, it was a much better air-to-air platform than previous F-4 variants.** *(USAF)*

extraordinary numbers of close air support missions in the more permissive South Vietnam and Laotian environments. Yet, as impressive as this was, the truth was worrying indeed: the United States' 7:1 kill ratio from Korea had dwindled to less than 2:1 over Vietnam.

There were many reasons for this erosion – cultural, training, tactics and SAC interference. But there were also technical limitations – the Phantom was big and unmanoeuvrable in comparison to the enemy's MiGs, its radar performed poorly when looking down into the 'weeds', it had no gun, and the weapons and technologies that should have given the F-4 crews an advantage just didn't work. Some of these failings were the result of the Air Force using a Navy fleet defence fighter (the radar worked well in look-down situations over water, for example), and some were because of SAC's earlier meddling in tactical fighter design and acquisition.

Accordingly, by the time the post-combat analysis and lessons learned briefings had been concluded post-Vietnam, the list of learning points was long. In fact, the Phantom's replacement had been under consideration since before the type's arrival in the skies of North Vietnam (late February 1965). Lieutenant Colonel John W. Bohn Jr examined the issue and authored a paper entitled 'Force Options for Tactical Air' that proposed a 'high-low mix' future force structure. Prompted by intelligence estimates which suggested that Soviet interceptors posed a greater threat than had originally been envisaged, Bohn's paper proposed the combination of a few high-tech (and high dollar) air-to-air fighters to sweep the Soviet defenders from the sky and a host of low tech (*ie* cheap) air-to-ground fighter-bombers to pound the enemy into submission.

Bohn originally suggested that the Northrop F-5 should fulfil the latter role, but he later recommended that a new high-technology fighter specifically designed to achieve aerial superiority – placing emphasis on manoeuvrability instead of speed – be developed in the near future. General John P. McConnell, Chief of Staff, USAF, endorsed the study and Eugene M. Zuckert, Secretary of the Air Force (SECAF), allocated $10 million for fiscal year 1966 for further studies leading to design of the ultimate US fighter.

Of the 500 designs submitted in October the next year, the USAF rejected all of them. None offered an airframe that would be optimised for the air-to-air role. In July 1967 the Soviets unveiled the MiG-25 Foxbat at the Domodadovo Air Show, a high-flying Mach 2.7 interceptor designed to counter the A-12/YF-12/SR-71 series of high, fast spy planes. The Foxbat sent shockwaves through the upper echelons of the USAF. In a two-year period, the MiG-25 was to further shock the West by breaking a number of world speed and time-

**RIGHT The MiG-25 'Foxbat' represented an enigmatic threat when it was revealed to the world in July 1967. For US intelligence analysts, it provided an opportunity to warn their nation's leaders that there could be no let-up in combating the USSR. The Foxbat therefore instilled urgency in the F-X programme.** *(USAF)*

to-altitude records. It provided the final impetus needed to spur the Pentagon and the American aerospace industry to ultimately produce what would become the F-15. The unveiling of the Foxbat paved the way for a second RFP (request for proposal) on 11 August 1967. This specifically asked for concept development of a 'Fighter' and went to all the contractors who had originally responded to the first RFP. By this time the air-to-air fighter was referred to as the 'F-X', meaning 'Fighter – Unknown number designation' (not 'Fighter Experimental', as is often reported), and it was clear that the F-X was to replace the F-4 Phantom.

## The F-X

The second RFP opened the door for unauthorised and initially unpopular work carried out by Major John R. Boyd to take centre stage in the future of aircraft design. Boyd, a test pilot and Korean War veteran, had developed a mathematical formula for defining the hypothetical performance, and hence the design, of a modern jet fighter. It was called the 'energy-manoeuvrability theory'. This concept, first published in May 1964, had been given little attention to date. It argued that a fighter's performance should be characterised by its potential and kinetic energies, each of which could be changed by manoeuvring the aircraft around the sky. It was this theory which would later mature into the 'Energy Manoeuvring' (EM) graph which fighter pilots now study to determine how many g they can pull and how fast they can turn their nose towards an opponent during combat.

The EM graph allowed designers to take an aerodynamic shape and plot what energy state, lift, drag and other criteria would be placed upon it at a range of altitudes and airspeeds. Armed with this information, and using expensive mainframe computers, they were able to determine how well it would manoeuvre and, importantly, which portion of the flight envelope it would perform in best.

This research would prove instrumental in both specifying the requirements for the F-X and evaluating the proposals of those contractors that responded to the second RFP. Among these were McDonnell Douglas, Lockheed, Grumman, General Dynamics, Fairchild Hiller and North American Aviation.

To counter the MiG-25, these companies would need to offer an F-X design that had an exceptional rate of climb (very high thrust) and a powerful radar able to detect fighter-size targets at long range, but the manoeuvrability to counter more nimble MiGs that were likely to enter service in the future.

Finding the right engines to power the F-X was Air Force Systems Command's (AFSC) responsibility, and they were looking for a large afterburning turbofan. AFSC's first proposal was for an augmented AB (afterburner) equipped turbofan with a bypass ratio of 2.2:1 (2.2 volumes of air via the fan bypass for each equivalent volume of air through the core turbojet).

However, knowledgeable pilots such as Boyd opposed it, saying that a 0.9:1 (almost equal flow of cool fan air and hot jet exhaust into the AB section) was preferred, because it made for more efficient afterburner operations. In combat, Boyd argued, an efficient afterburner was more important than fuel economy. Initially a compromise of 1.5:1 was agreed and studies were sourced to General Electric (GE) and Pratt & Whitney (P&W) while AFSC's Aeronautical Propulsion Laboratory undertook its own evaluation.

At this stage (1967), the Department of Defense stepped in and directed that the Navy and Air Force use the same compressor/turbine core for its future AB turbofans (for the Grumman F-14B Tomcat and F-X), eliminating the opportunity for further optimisation and setting the ratio for the F-X's concept motor at 0.7:1, increasing operating temperatures, compression ratio, weight and cost in doing so. While 0.7:1 was better than 1.5:1, by this time the further studies had determined that 0.6:1 was best.

Studies were completed in September 1967 and the USAF was given the lead to develop the common engine core the following April. The joint programme went by the name Advanced Turbine Engine Gas Generator (ATEGG), and drew on experiences learned through the General Electric TF-30, the engine which powered the troubled F-111 bomber and the F-14A. GE, General Motors (GM) and P&W

**ABOVE AND BELOW**
**The General Dynamics F-111A and Grumman F-14A both feature variable geometry wings – they could sweep their wings back and forth, according to the phase of flight. 'VG' wings were heavy, complex and at the time still prone to problems. McAir opted to stick with a traditional fixed geometry wing for its F-X design.** *(USAF)*

were sent requests for proposals in April 1968. GM was eliminated from the programme four months later, leaving P&W and GE to complete a $118m contract for 'the initial engineering development of the F-X engine'.

Although the F-X would initially utilise newer, improved versions of the AIM-7 Sparrow and AIM-9 Sidewinder air-to-air missiles, a powerful new radar was needed that could see small radar-cross-section targets, such as the MiG-21, at great ranges and be able to look below the altitude of the fighter to find such targets against the heavy electronic clutter of 'ground returns'. As the USAF had experienced in South-East Asia, opposing fighters could 'hide' amongst this clutter and be almost impossible to detect amongst the many extraneous returns.

The solution to this problem was in the development of Doppler radars. Since its invention radar had worked on the concept of sending out a 'pulse' of energy and, by measuring the time for that 'pulse' to be reflected back to the radar, the range to the target could be determined. Doppler radars worked on the theory that returns from approaching targets would be compressed by the closing speed of the target, increasing the frequency of the returning 'pulse'. Conversely, a target that was going away would reflect back a pulse that would be expanded – and thus at a lower frequency – from its original form. By measuring the changes in the frequency in the returning 'pulse' it is possible to determine whether the target is approaching or departing and at what speed.

Both Hughes and Westinghouse had developed the Doppler radar technology into practical applications and were poised to work them into the sophisticated fighter-size package needed for the F-X. In March 1968 both were issued competitive awards to provide a useable long-range, look-down radar, to be the 'Eyes of the Eagle'.

The winning bid would be the one that combined these primary components – airframe, engines and radar – into the most efficient (in terms of cost), effective and manoeuvrable combination. The process was very much aided by the use of Boyd's EM

theory, which proved instrumental in the second round of proposals. For one thing, it showed that the projected weight of the F-X could be reduced to 40,000lb. Boyd argued that it should be even lighter.

Fortunately for McDonnell Douglas, the company had continued to develop their initial F-X design study with in-house funding and were well placed to respond to the second RFP. The team had dispensed with the variable geometry (VG) wing design that was particularly in vogue at the time (as used on the F-111 and F-14), and had instead designed a fighter with a very robust airframe-engine combination in the 40,000lb weight category.

Meanwhile, Lockheed, Grumman and General Dynamics continued their preference for a VG wing. Consequently, on 1 December 1967 the USAF chose one contender from each of the two 'schools' of configurations: McDonnell Douglas with its fixed-wing design, and General Dynamics (GD) using its VG technology from building the F-111. Contracts were awarded to these two to refine their F-X proposals.

## From F-X to F-15

At this stage the F-X's true customer, Tactical Air Command (TAC), weighed in to make its preferences and requirements known. By this time, February 1968, TAC had changed from a training command into a combat command, responsible for providing units (as well as training aircrews) to the overseas commands in Europe and the Pacific. Following a series of conferences hosted by TAC at Langley AFB, Virginia, TAC could speak for all three tactical combat commands: TAC, United States Air Forces in Europe (USAFE) and Pacific Air Command (PACAF). Collectively, these were known as the Tactical Air Forces, or TAF. TAC was now ordering its 'next generation' fighter.

TAC's requirement was for a high-performance fighter optimised to engage and kill its adversaries while still beyond visual range (BVR), and once they closed to the 'visual arena' to be able to outmanoeuvre the enemy to gain a shooting advantage. Although the inclusion of an internal gun was not specified, it went without saying that the lack of one would disqualify the competing contractor. Three months later, in May 1968, CSAF General John P. McConnell endorsed TAC's required operational capability and assigned the F-X the Air Force's highest priority. The USAF would have air superiority and would have it as soon as possible!

In June 1968 the USAF took the results of the two contractors' proposals for evaluation. Several factors caused considerable disagreement amongst the hundred or so individuals assigned to the review board, but none more so than the avionics suite. The disagreement stemmed from the rather schizophrenic concept still being pursued by the USAF. While the TAF was convinced that only a specialised air superiority fighter would do (and the CSAF endorsed that requirement), the Air Force's civilian masters had ensured that the ground attack requirements were retained in the design specification given to the contractors.

So the review initially hung up on something the TAF didn't want anyway: whether or not the design should retain a TFR (terrain following radar) and related all-weather bombing systems. These would allow the aircraft to bomb targets when they might not be visible to the pilot. Advocates argued that it should be able to, especially given the fact that technology was advancing rapidly enough to allow the carriage of such systems with only a small weight penalty. Those against the idea argued that there were unacceptable risks in making such assumptions and that, in any case, these items were not essential and were costly overall.

There was also a strong voice amongst the ranks of the combat-experienced fighter pilots on the Air Staff, who reasoned that the high-tech yet manoeuvrable 40,000lb missile-shooter was never going to succeed, and that a smaller 25,000lb fighter with simple avionics and super-manoeuvrability was the way forward. Boyd was one of those to argue this point.

Many of these veterans had witnessed the devastating effectiveness of NVN's MiG-21s against the heavier and visually more discernible F-4. Indeed, this had been confirmed by classified USAF and USN projects in remote ranges in Nevada, where secretly acquired MiGs had been flight tested and evaluated against nearly every fighter in the US inventory.

In many respects, this band of dissidents – known infamously as the 'Fighter Mafia' – were right to be sceptical of the success of what, to them, looked like just another F-4.

The review culminated in the Development Concept Paper (DCP) signed by the (now) SECAF Harold Brown in September 1968. The DCP had determined that the aircraft was to be a single-seat twin turbofan-powered fighter of not more than 40,000lb. It would have a thrust-to-weight ratio approaching 1:1 at combat weight; a maximum speed of Mach 2.5; 360° view outside the pilot's cockpit and advanced display and controls layout inside; be capable of flying a 260nm mission on internal fuel and able to deploy to Europe without in-flight refuelling (with external fuel tanks) and have a long range pulse-Doppler radar with a look-down capability. In plain English, the USAF finally stated unequivocally that it wanted a single-seat fighter with twin-engine-survivability which could outmanoeuvre and out gun any enemy fighter in the world either BVR or in the visual arena. In addition, the USAF decreed that the engine, radar and other major components would be tendered for on a prototype basis – a move designed to attract the best systems at the least risk to the Air Force. The fly-away cost was estimated at around $5.3 million each. The F-X airframe, once chosen, was to be called the F-15.

The DCP resulted in a third RFP, this one for contract definition, which was released on 30 September to the seven original contractors plus Ling-Temco-Vought. Evaluating the responses three months later, the USAF awarded $15.4m contracts to McDonnell Douglas, North American Rockwell and Fairchild Hiller for the final stage of development. These three contractors – none of which used the VG configuration – were to determine the definitive layout and provide prospective performance figures for each of their preferred designs. The RFP called for each of the three companies to provide their final design by 30 June 1969.

Their responses were all received on time. McDonnell Douglas' proposal was the most comprehensive it had ever prepared, consisting of 37,000 pages that stood 11ft high. They went with the conventional layout with twin fins. North American Rockwell's was an advanced 'blended wing-body' with fuselage-embedded engines and a single fin, and Fairchild Hiller's design had wing-mounted engines, 'cranked wing' and a single fin. For the next six months the USAF's F-15 Systems Project Office (SPO) evaluated the proposals.

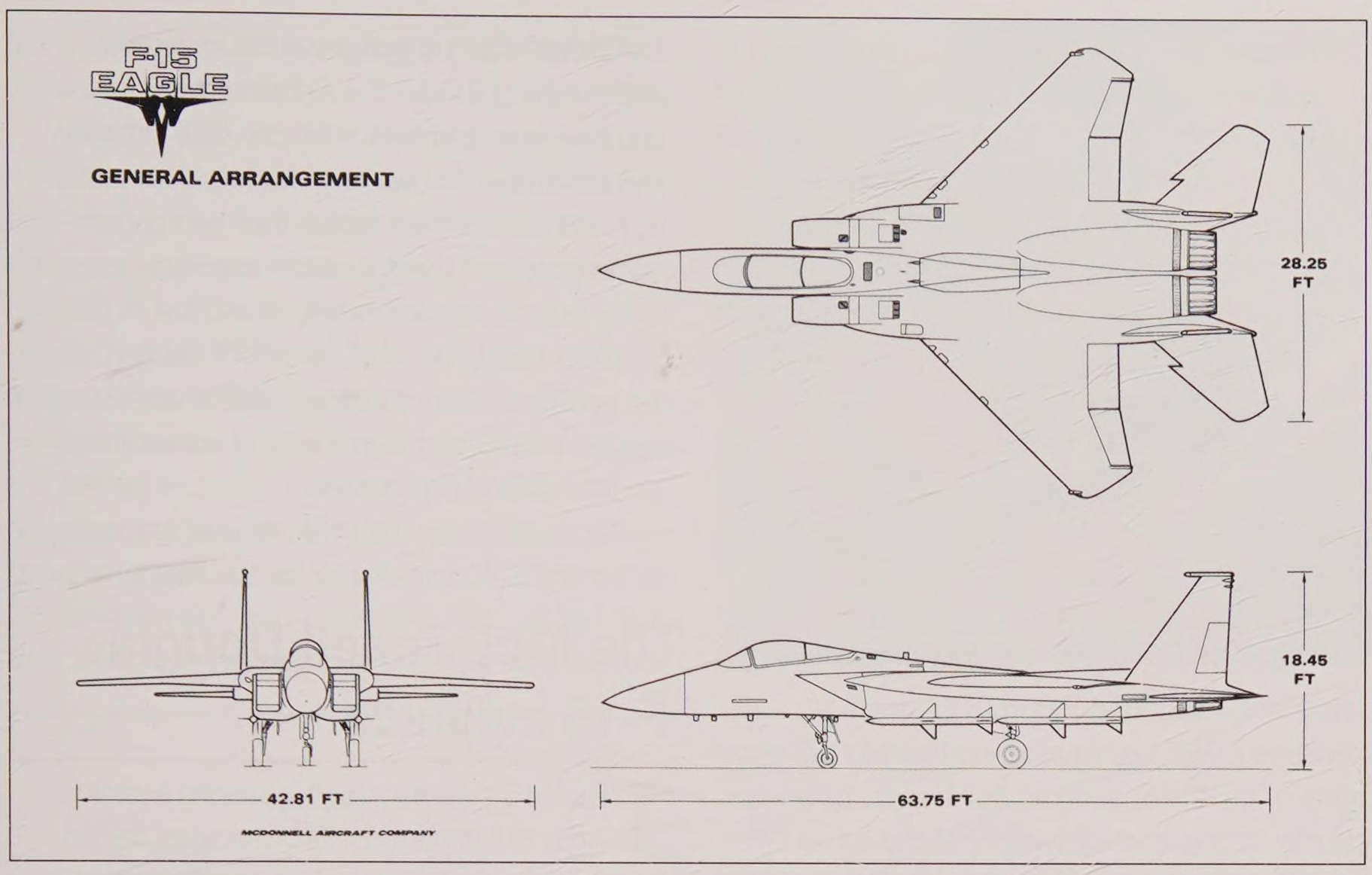
McDonnell Douglas' effort, and 2,500,000 man hours of work, paid off at 1620hr, Tuesday 23 December 1969, when Brigadier General Benjamin N. Bellis, the Air Force's system programme manager for the F-15, telephoned Sandy McDonnell in St Louis: McAir had won the F-X competition.

## The McDonnell Douglas 199-B design

The Aircraft Company division of McDonnell Douglas – often called 'McAir' – was told to prepare for an eventual production run of 749 airframes. The company was tasked by the Air Force to produce 20 test aircraft, and then to deliver 'a first wing of 107 F-15 aircraft at a "not-to-exceed" ceiling price of $936,591,000'. The test aircraft were to be manufactured at a cost of some $1,146,385,000.

McDonnell Douglas' design would incorporate avionics, flight controls, electronic warfare systems, weapons delivery capabilities and maintainability never before seen. The Eagle would boast a large number of 'firsts' and would be developed in such a way that these facets would all combine to make the ultimate air superiority fighter.

McDonnell Douglas had spent more than 23,000 hours wind-tunnel testing over 100 different wing/body combinations before it felt it had the best wing shape for the 199-B. Considerable time was spent optimising the aerofoil for minimum drag in both low- and high-altitude flight regimes. What resulted was a sophisticated, highly cambered wing shape devoid of any high-lift devices as seen on the slatted F-4E, and one which conferred excellent manoeuvrability even when under high-g loading. Joe Dobronski, McAir test pilot, concluded that, 'agility throughout the flight envelope of the F-15 belies its size. Its light and responsive control system, along with low wing-loading and high thrust-to-weight ratio, result in exciting flight control characteristics

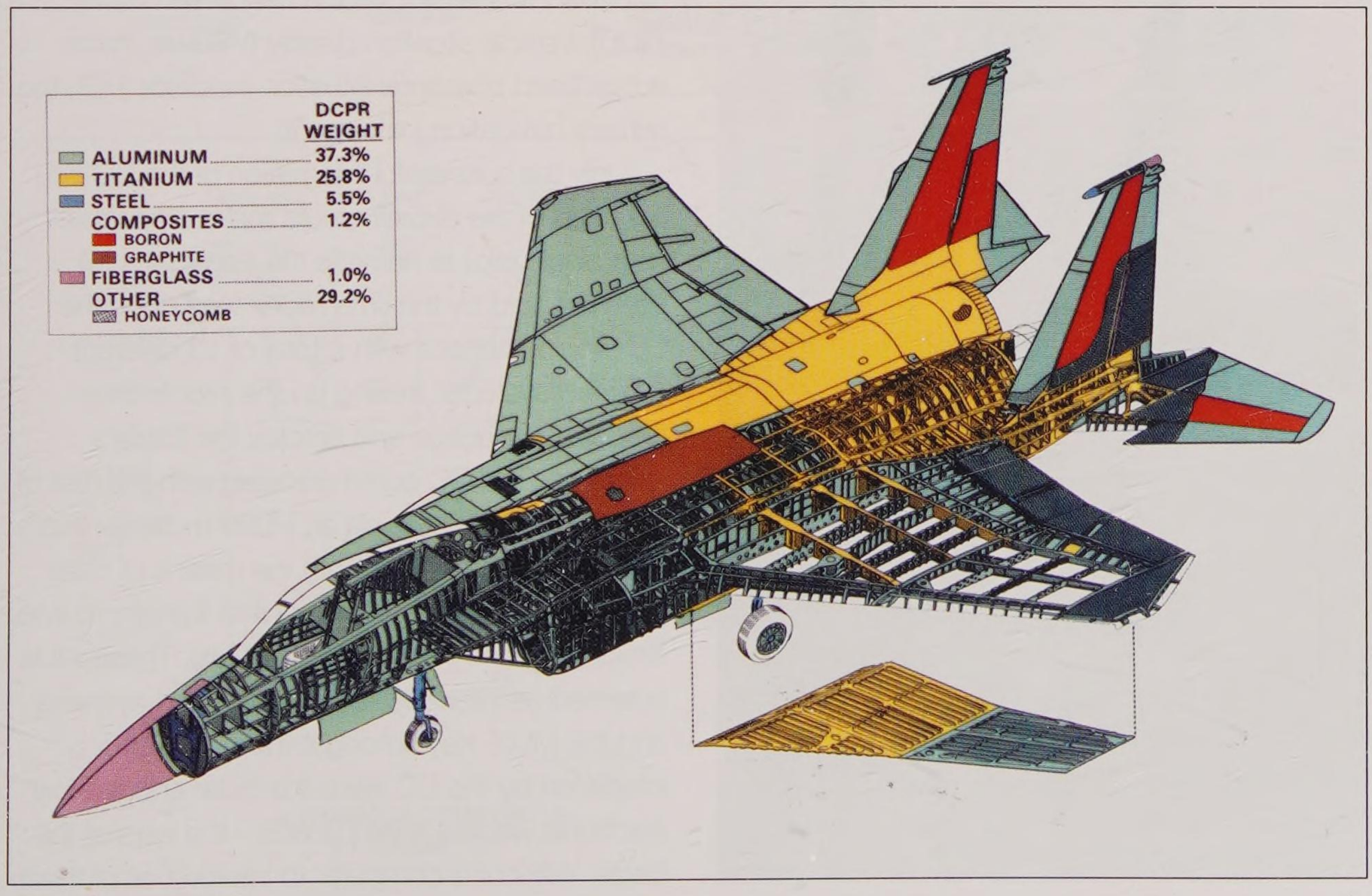



**LEFT The general arrangement of the F-15, formerly McAir's Model 199B design, shows it to be a large, twin-tail, twin-engine design with significant wing, fuselage and empenage total surface area.** *(USAF)*

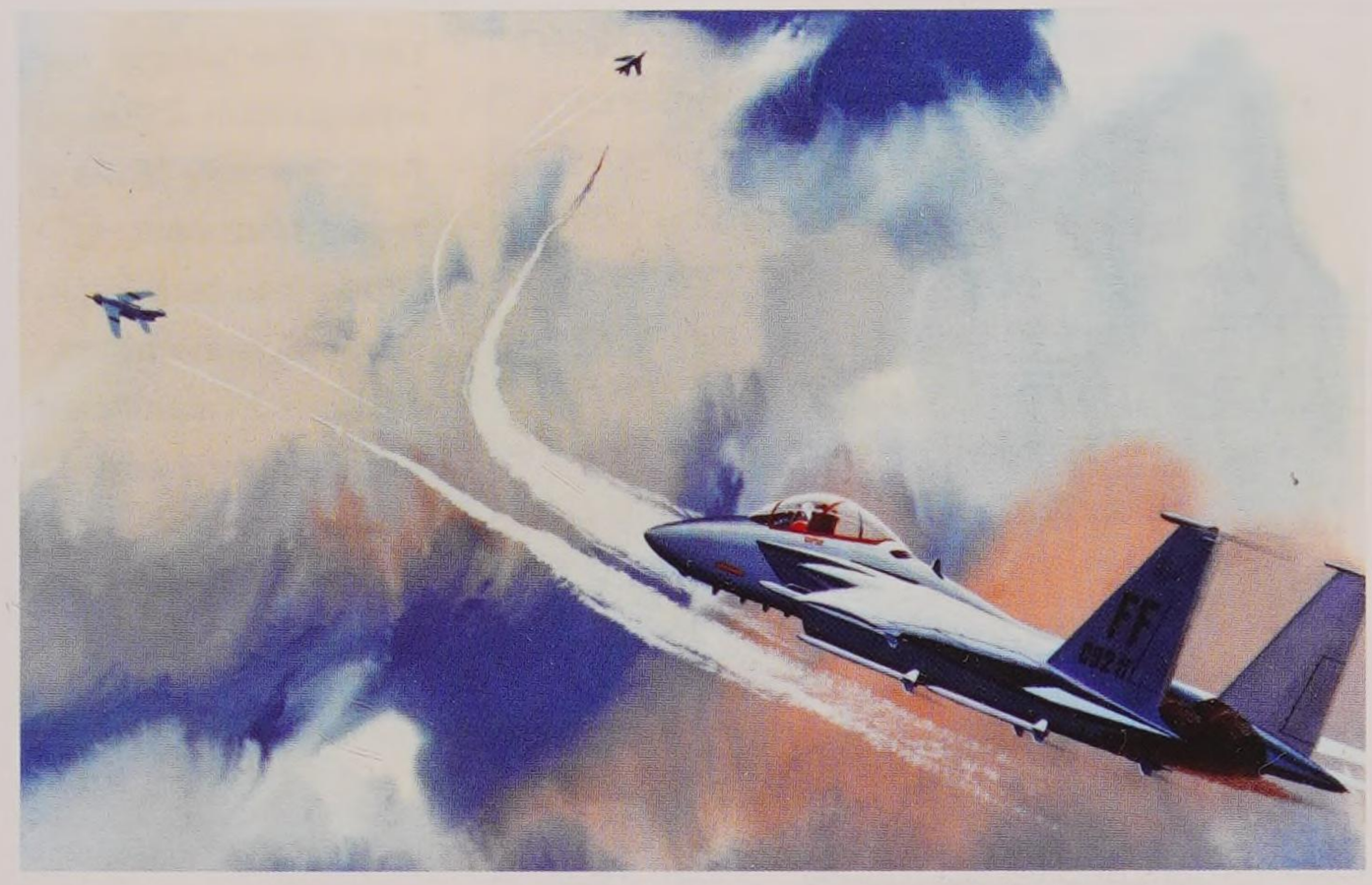
for air combat manoeuvring' and generated a 16° per second instantaneous turn rate and a refreshingly slow landing speed of around 120kt.

From the outset, McAir's F-X contender had been designed to be easy to manufacture and maintain. New manufacturing techniques and materials would allow it to be built in a shorter time period and with less production effort than its competitors. The fuselage was simple in construction, built from a mere three sections assembled to form a whole, giving it a 4,000-hour fatigue life (300% more than the F-4).

The team effort required to build the F-15 would eventually involve no fewer than 4,000 sub-contractors. Fabrication was first on the list; aluminium, titanium, steel, fibreglass and composites such as boron epoxy and honeycomb were all used by the aircraft fabricators to create the many pieces that made up the Eagle. Titanium was particularly

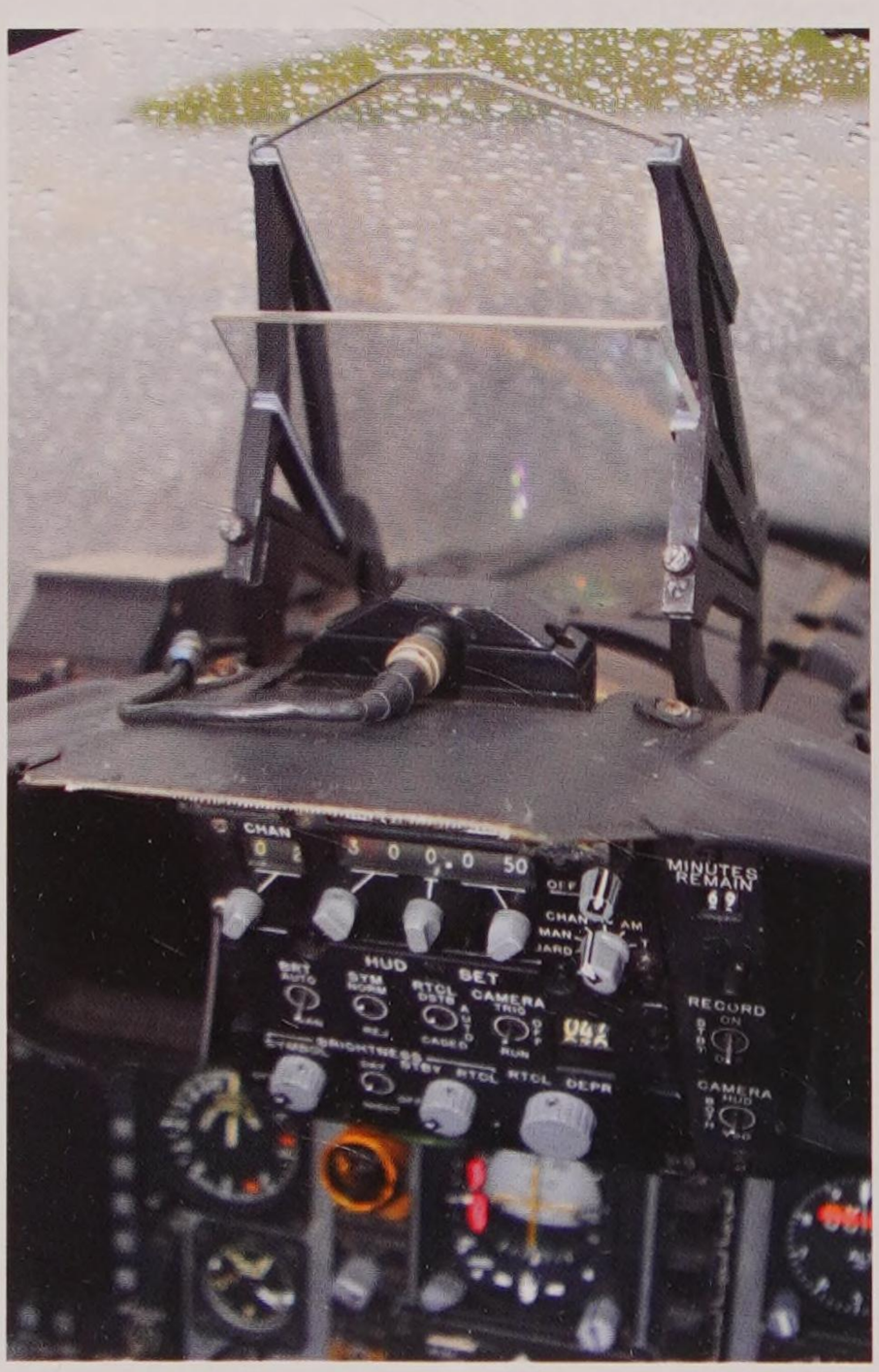



**LEFT Advances in manufacturing technology meant that the majority of the F-X would be constructed from aluminium and titanium. As this breakdown shows, titanium would make up 25.8% of the F-15 compared to only 9% in the F-4.** *(Boeing via Steve Davies)*



**ABOVE A McAir artist's impression of the Model 199B in action. Note the simultaneous engagement of two targets ... an event that would take place for real for the first time ever in 1999.** *(USAF)*

important – although tough to fabricate – because it was key to allowing the 'big bone' parts of the F-15, such as bulkheads, to be equally strong and lightweight at the same time. Working with this tough metal required the use of multi-axis, multi-spindle computer-controlled profilers, which could machine a 1,250lb billet of titanium into a complex 145lb bulkhead. Titanium would make up 25.8% of the airframe (versus 9% in the F-4) forming the full-depth fuselage keel, wing spars, stabiliser frames, torque boxes and individual engine bays.




**RIGHT The A-7 Corsair II was the first US military aircraft to feature a head-up display, but the Eagle was the first pure fighter to have one. Situated at the pilot's eye-line, it projects flight, navigation and weapons symbology against the two panes of glass.** *(Steve Davies/ FJPhotography.com)*

To cater for the extensive avionics and electronics built into the airframe, miniature compact wire bundles – which were another weight-saving innovation – had to be braided by hand across long tables that had pegs hammered into them to allow the technicians to lay out the cabling neatly. In all, the F-15 required nearly 19 miles' worth of cabling, and the end result was that the Eagle's wire bundles weighed 45% less than those of comparable length installed on the F-4.

Come October 1971, McAir was on track to get the F-15 into the air for the first time in July 1972.

## F-15 avionics

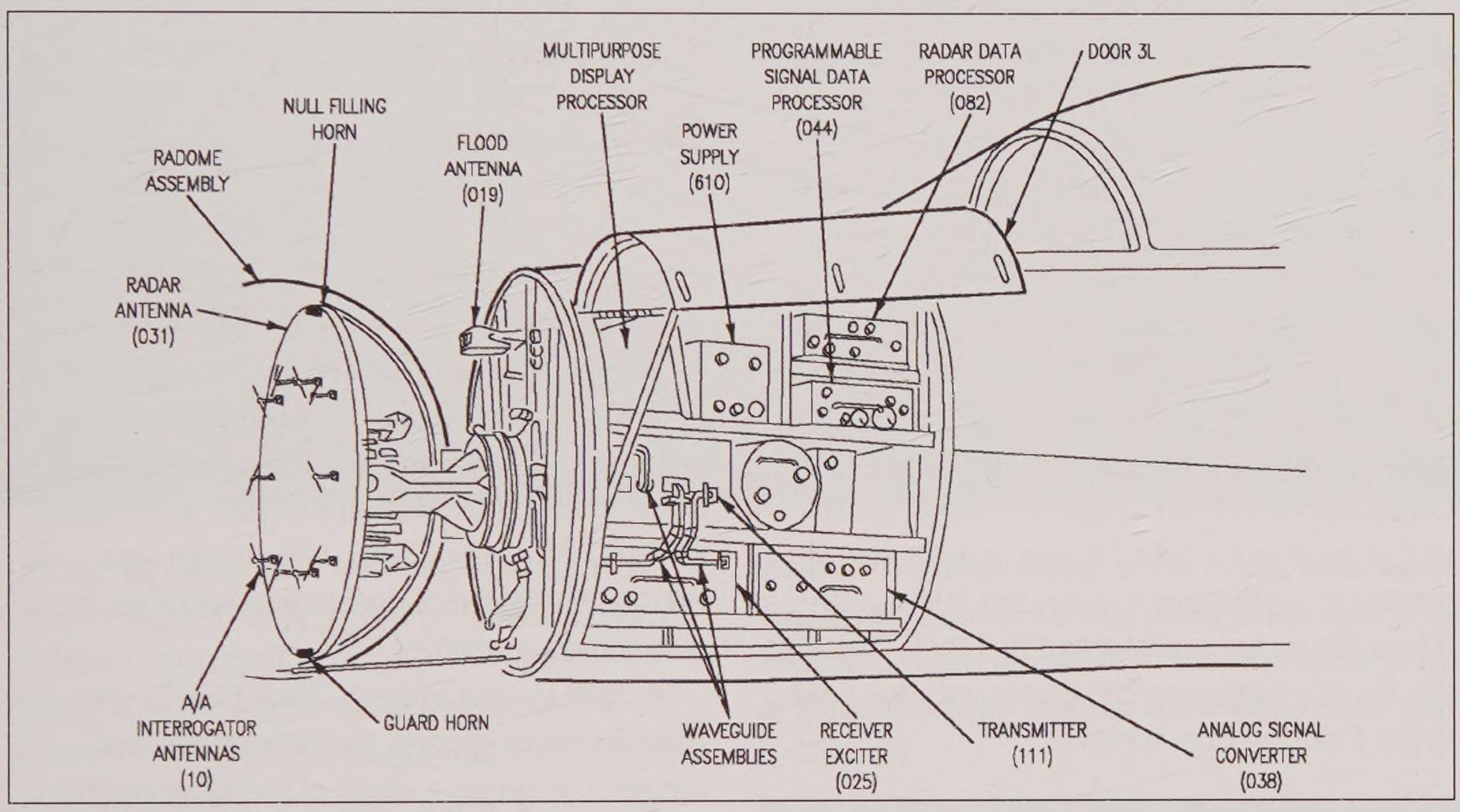
The F-15's avionics and weapons systems were to be the most sophisticated fielded in any fighter at that time. They would be tied together and controlled by an IBM CP-1075/ AYK central computer (CC), a 48.5lb high-speed, general-purpose analogue computer of a kind never before seen. It had a 'hard-wired' memory of 16.3K – 34bit – words, expandable to 24.6K, to 'remember' weapons envelopes and aircraft flight performance data. Its computation speed of 340,000 instructions per second was used to convert the data sent from subsystems onboard the aircraft into useful and readable information displayed to the pilot on the heads-up display (HUD), vertical situation display (VSD, or 'radar scope') and horizontal situation indicator (HSI, the primary navigation instrument).

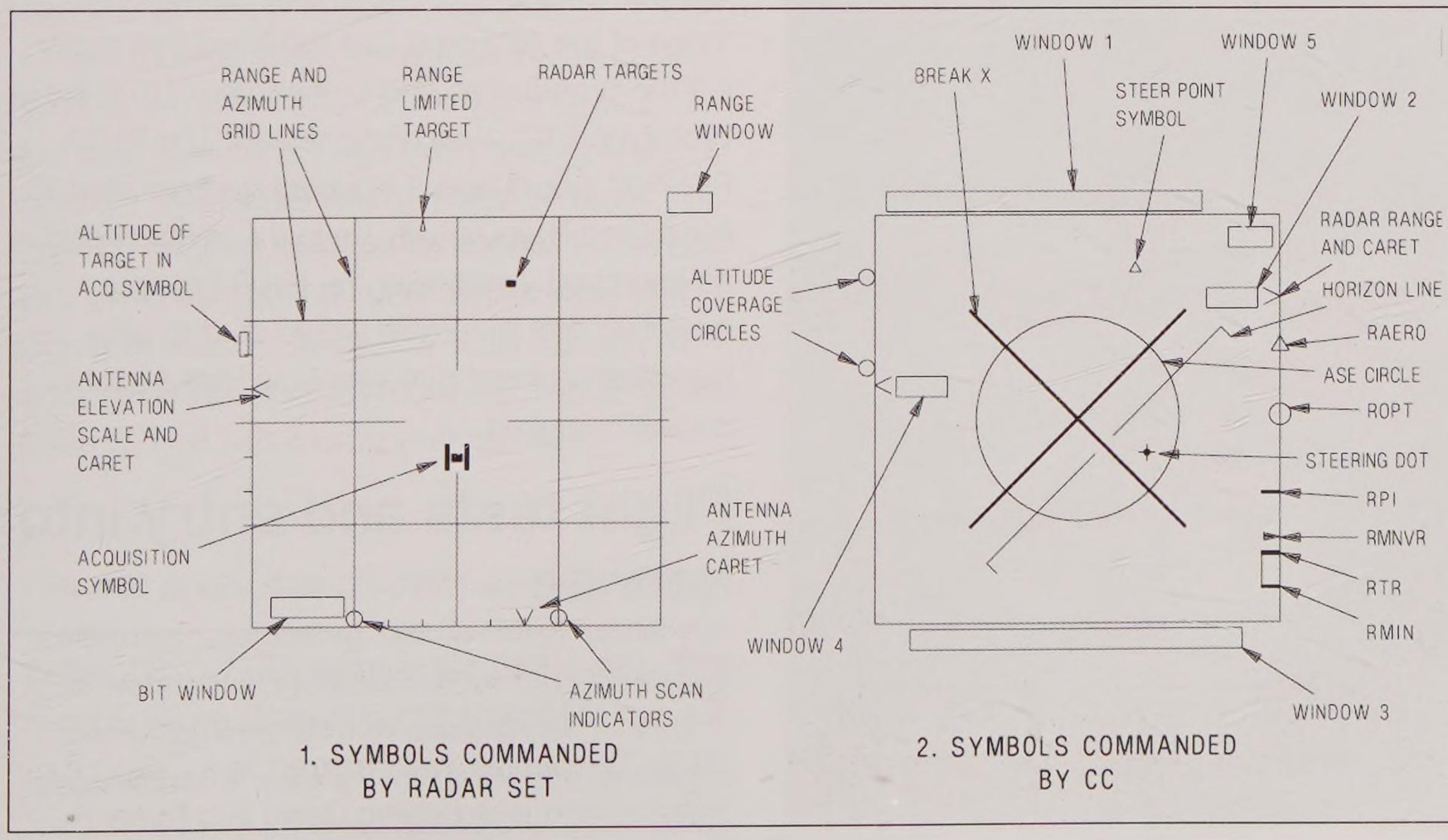
Only the successful integration of the CC into the heart of the aircraft would make it possible for a single pilot to harness the Eagle jet's full potential, and by the time McAir was done the CC would interface with a total of 13 different onboard systems, freeing up the pilot in the process to manage and employ the Eagle's weapons. The CC communicated with the rest of the aircraft's systems via an H009 multiplex bus (MUX), which provided both the means of data transfer and the scheduling of that transfer to two aircraft avionics interface units (AIUs). These AIUs operated as interfaces between aircraft systems and the MUX. Key amongst those systems interfaced by the CC were the radar and tactical electronic warfare suite (TEWS) – the ears of the Eagle. Without a computer to interpret all of these

many sources of data, the Eagle's potency would be seriously degraded.

While the CC was effectively the brains of the jet and allowed automation of systems that were formerly operated by the Phantom's weapons systems officer (WSO), the 'eyes of the Eagle' were its extremely sophisticated pulse-Doppler (PD) radar. Hughes had been awarded the tender to build a radar for the F-X programme in 1968, and had settled on the following design philosophy: produce an advanced radar with a limited capability against ground targets, an all-weather capability against airborne threats, and provisions for cueing optical tracking systems which may be installed at a later date. Chosen by McAir and approved by the USAF, Hughes received an $82 million contract on 30 September 1970 to build what was to become the AN/APG-63 radar.

The APG-63 was a coherent PD radar that held numerous advantages over the older Westinghouse APQ-100/109A pulse radar housed in the nose of the F-4C/D. While the Phantom radars used low pulse repetition frequencies (PRFs), the APG-63 employed high PRF (HPRF) to locate and track targets in ground clutter using Doppler shift, and medium PRF (MPRF) to 'fine tune' range data for weapons employment. Thus it could track targets at different ranges, formations,




**LEFT The APG-63 radar set would equip the F-15, interfacing with the new central computer (CC) to provide the pilot with a synthetic view of the radar picture. While some symbology would be calculated by the radar (typically radar and target information), the CC would number-crunch the remaining data to provide such information as the weapons employment zone (WEZ) for the AIM-9 Sidewinder or AIM-7 Sparrow missiles.** *(USAF)*

**RIGHT The 'clean' look of the VSD (vertical situation display), or radar scope, came courtesy of the advanced computing power of the Eagle. In this image, a single target is being tracked, with WEZ data provided by the circular and triangular cues down the right side of the display.** *(USAF)*

closing speeds and altitudes relative to itself. It could also interrogate a contact using the Hazeltine APX-76 IFF (identification friend or foe) interrogator and Litton reply evaluator, in order to determine if it was friendly or not. Early PD radars had been good in the head-on, look-down environment, but had been weak in tail-on and manoeuvring situations. The APG-63 addressed these two weaknesses by automatically interleaving high- and medium-PRFs. Whereas the F-4's radar historically had a 40nm search and 10nm lock-on range and could not look down at all, the F-15's system would be able to detect fighter-size targets in a look-up environment at around 80nm, with a look-down capability about half that. Overall the Eagle's radar search volume was 4.3 times larger than the Phantom's.

**BELOW Article 'F-1' (71-0280) sets up for landing following a successful first flight. Once in production, the F-15 would feature sawtooth leading edges on the horizontal stabilators.** *(Boeing)*

For the first time, the radar displayed a 'clean' synthetic image to the pilot. This meant that the pilot looked not at the raw echoes detected by the radar, but at clear and easily interpreted symbology on the VSD. And the F-15 cockpit was designed with maximum armament delivery capability in mind, and specifically to allow the pilot to look for, detect, acquire, identify and fire at an approaching target without ever having to take his hands off the throttle and stick. Hands-on throttle and stick – HOTAS – was born (see page 106).

On 27 February 1970, a $448m contract was awarded to P&W to produce the 'common compressor/turbine core' afterburning turbofan going by the cumbersome and confused DoD-directed name of Advanced Turbine Engine Gas Generator (ATEGG). The proposed ATEGG had its roots in three engines already produced by P&W: the TF-30-P-1 for the F-111, the TF-30-P-412 for the F-14A and the J-58 for the SR-71. P&W planned to accommodate the differing needs of the USN and USAF by building a 'standard core' but substituting larger fans, fan ducting and a different afterburner to provide the increased thrust required by the Navy. The contract called for P&W to produce 90 F100-PW-100 (USAF designation) and F401-PW-400 (USN designation) engines for test and evaluation.

A Joint Engine Project Office (JEPO) was established to iron out the differences that naturally arose as a result of the Navy having requirements of the engine that differed from those of the Air Force, but the Navy eventually left the programme and by February 1972 the prototype F100 was being tested. The F100-PW-100 would lead a troubled life from start to finish, and it would only be in the years ahead, as improved versions of the F100 became available, that the Eagle would start to offer the carefree throttle movements that a pilot in combat required.

## Flight tests and entry into service

F-15A-1-MC, tail number AF71-0280, rolled out of McAir's St Louis plant on 26 June 1972. The aircraft was referred to as 'F-1'. Flight testing was broken down into three

phases or categories: Category I, Contractor Development Test & Evaluation (CDT&E), which received 12 aircraft (71-0280 – 71-0291); Category II, Air Force Development Test & Evaluation (AFDT&E) with eight aircraft (72-0113 – 72-0120); and Category III, Follow-on Operational Test & Evaluation (FOT&E).

Two months after F-1 took to the air Eagle Number 2 (AF71-0281 or 'F-2') first flew and was used as a 'propulsion development vehicle'. There were two series of YF100-PW-100 engines available to the test force, but early on in the CDT&E cycle this was the only aircraft to feature Series II YF100s capable of producing rated thrust. Additional Eagles arrived at the CTF at two-month intervals, with F-7

**RIGHT Article 'F-8' (71-0287) was used for high AOA and spin testing, but also took on the role of testing fuel systems and air-to-air refuelling characteristics. Like all designs during the F-X programme, it wore a white and high-vis orange colour scheme.** *(Boeing via Steve Davies)*

**ABOVE The 'front office' of the F-15A. Note the ancient 8mm gun camera film controls (silver vertical panel to the right of the HUD and main UHF controls), which predated VCR tape recorders. Just below the glareshield is the radar scope (VSD) to the left, and radar warning receiver to the right.** *(USAF)*

**ABOVE Co-author Doug 'Disco' Dildy guns an Aggressor F-5 high over the Nevada desert. The HUD film shows how even at 23,600ft MSL the Eagle can pull almost 5g to track the threat. The hard-turning fight has slowed down to 305kt, with the F-5 even slower (note 105kt of overtake). The 'XXX' in the lower left means the M61A1 Gatling gun is 'SAFE', and the bright light in the upper right (called a 'witness mark') means that the trigger is fully depressed.** *(Author's collection)*

**BELOW Three Luke AFB Eagles ('LA' tailcode) from the 'Highly Renowned and World Famous Triple Nickel' Tactical Fighter Training Squadron formate high above the Arizona desert. Note that the nearest F-15A carries a blue AIM-9P practice training missile (PTM) on station 2A.** *(USAF)*

(AF71-0286) being the first to be flown non-stop from St Louis to Edwards AFB, by McAir test pilot Jack Knights, on 29 June 1973. The eighth Eagle off the pre-production assembly line was the first two-seat TF-15A, known as 'TF-1', and was delivered only nine days later. Over the next three years the Eagle was thoroughly tested and was found to be a worthy winner of the F-X competition.

The delivery of the first production-specification F-15 at Luke AFB, on 14 November 1974, took place in the presence of the President of the United States, Gerald R. Ford. The aircraft was the 21st Eagle built, a two-seat TF-15A-7-MC, serial number AF73-0108 (also known as TF-3), and it had 'TAC 1' emblazoned on the nose. It was delivered to 555th Tactical Fighter Training Squadron.

In the latter stages of testing in 1976, the Eagle was operated out of Luke AFB by the 58th TFTW (tactical fighter training wing) for FOT&E. The unit tested the APG-63 against multiple targets at Nellis AFB. Dissimilar air combat training (DACT) was evaluated against some 900 adversary support sorties flown by F-5E Aggressors, Air Defence Command F-106s, and the Navy's 'Top Gun' fighter weapons school F-14As. The 'new'

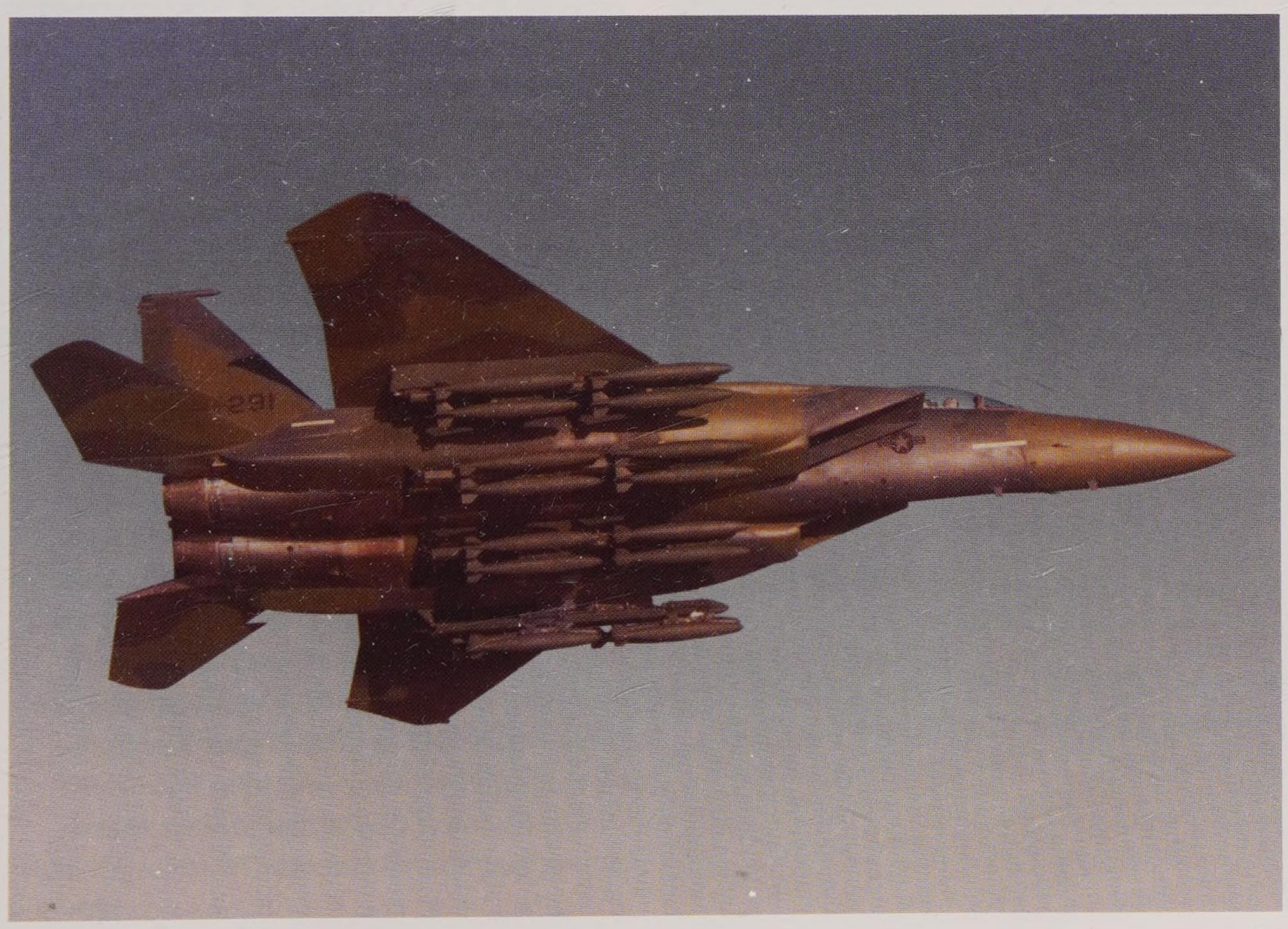
M61A1 Vulcan cannon was fired at Eglin AFB and AIM-7Fs and early AIM-9s were shot at White Sands Army Missile Range, New Mexico, and China Lake Naval Weapons Test Centre, California. FOT&E formally concluded in July 1976.

By the end of fiscal year 1977, 245 F-15s had been delivered and TAC had met its objective of providing two fully equipped combat-ready wings – 76 jets were at Langley with the 'First Wing' and 73 were on the front lines of the 'Cold War' at 36th TFW, Bitburg AB, Germany. Fifty more were at Luke with the 58th TFW's training squadrons and the 57th FWW had another 14 at Nellis. As shiny new Eagle jets continued to roll off the production line at a rate of nine per month, the third USAF Eagle wing began its conversion to the F-15. It was the 'dual based' 49th TFW (Tailcode 'HO') stationed stateside at Holloman AFB, Alamogordo, New Mexico. In December 1977 the TF-15 was officially redesigned the F-15B.

**ABOVE The 555th TFTS had a large number of two-seat 'tubs' or 'family models' for initial transition training, learning aircraft handling, patterns and landings, and instrument procedures. Aircraft 76-130 was delivered on 26 September 1977 and flew as an RTU trainer at Luke and Tyndall AFBs until July 1991, when it was transferred to the 445th Test Squadron, 412th Test Wing at Edwards AFB, California.** *(USAF)*

## F-15C/D Eagle

Barring problems experienced with the PW-100 engine, the Eagle's entry to service had been a huge success. Even so, McAir had been hard at work developing the next version of the Eagle – the F-15C and F-15D single- and two-seater respectively. The first squadron slated to operate this type was



**LEFT The Dual Role Fighter demonstrator, F-15B '291, was used by McAir to show off the potential that the Eagle had as a potent successor to the F-111. Seen here with early conformal fuel tanks and a full load of cluster bombers, '291 would eventually receive a 'European 1' green and grey wraparound camouflage scheme.** *(Boeing via Steve Davies)*

**RIGHT F-15As of the 27th, 71st and 94th Tactical Fighter Squadrons formate on the 1st Tactical Fighter Wing's flagship over Fort Monroe, Virginia, in this very early 1980s photograph. All four jets carry live AIM-7 and AIM-9 loads.** *(USAF)*

**BELOW The 71st TFS 'Ironmen's' flagship, F-15A 76-071, flies over the harbour of Hampton, Virginia. This 'boss's jet' had the ignominious distinction of being badly damaged when another 71st TFS F-15A (76-076) jumped its chocks during an engine run on the ramp and rammed it, on 12 November 1983. Both aircraft were subsequently repaired. Aircraft 76-071 went to AMARC, while 76-076 went for permanent display in a park near DeBary, Florida.** *(USAF)*

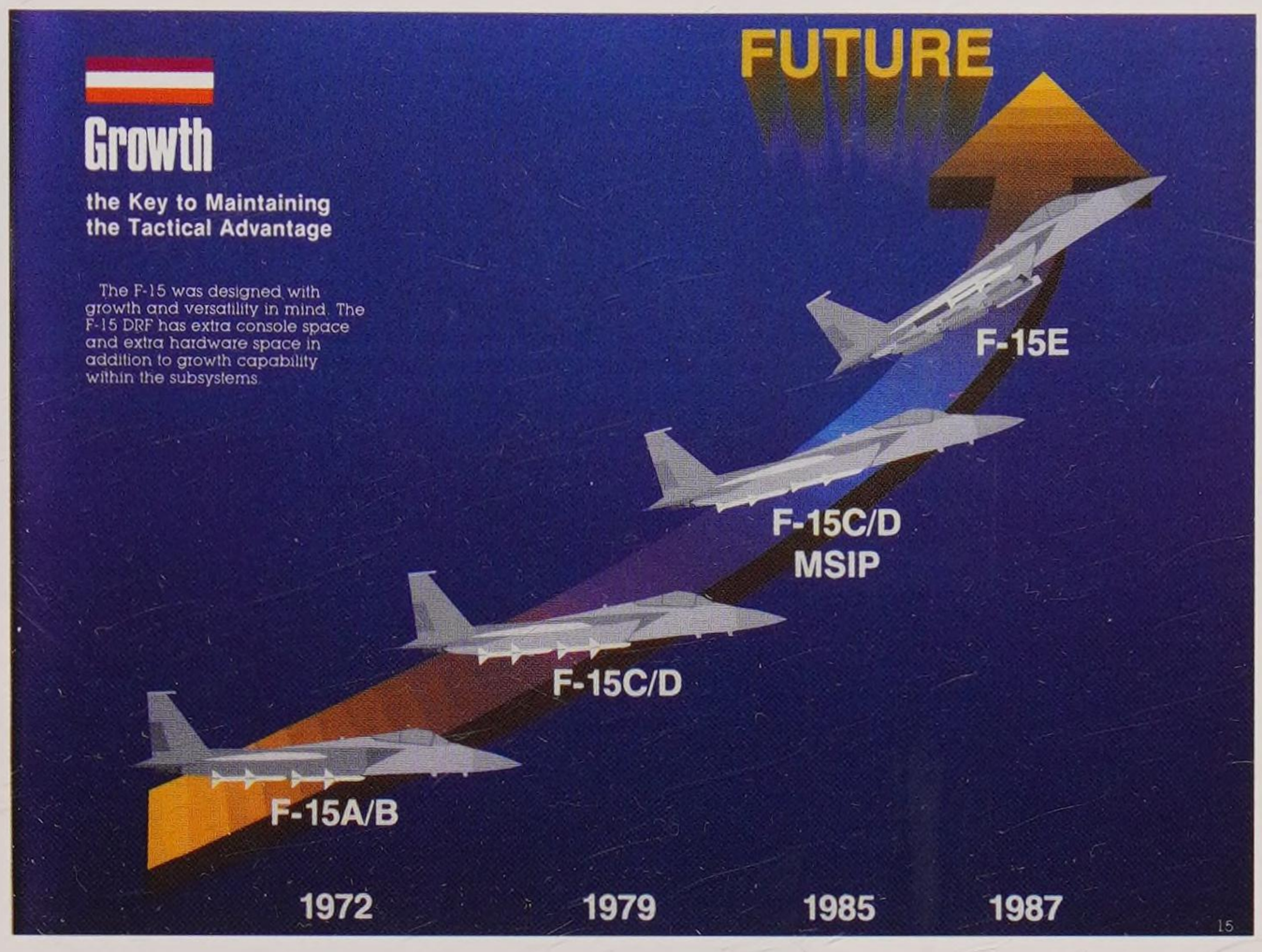
PACAF's 18th TFW operating out of Kadena AB, Japan.

The first F-15C delivered to an operational unit (AF78-0470) was accepted on 3 July 1979 by the 60th TFS at Eglin, the squadron tasked with preparing the Kadena squadrons to operate their new jets. Sixteen F-15C/Ds were delivered to Okinawa AB on 26 September that year, and by 16 April 1980 the 33rd TFW had sent two more fully-equipped squadrons to Kadena.

The new F-15C was the definitive version of the mighty Eagle. While externally it appeared very little different there were significant interior modifications, making a powerful air-to-air fighter even stronger. McAir engineers had built in significant 'room for growth', and the C-model took advantage of that available space. Internally, the two wing and main fuselage tanks were increased to hold an additional 1,950lb (300 US gal), and the C-model came equipped with the plumbing, pneumatics and electrical connections to carry the conformal fuel tanks (CFTs), called 'saddlebags' because of the way they hung on the flanks of the jet. These provided the potential to carry an additional 9,800lb and fly for 5 hours 20 minutes without external tanks or air-to-air refuelling (AAR).

The total fuel carriage capability of the F-15C was 35,100lb. In order to lift this much gas most of the airframe structure required beefing up, increasing the empty weight of the aircraft by 1,500lb to 29,000lb total. This in turn required much more robust landing gear to support it on the ground. Additionally, the landing gear was mounted slightly differently in the C-model. The vertical alignment of the A-model's gear made it tricky to land in high crosswinds since the breeze could easily lift the upwind wing, tipping the aircraft to one side and causing it to drift towards the runway edge. The C-model's legs were therefore angled outward about 4°, barely enough to be discernible but enough to keep the jet from 'tipping over' in crosswinds.

Other internal differences could only be appreciated from the cockpit. Beginning with the radar in the nose, the APG-63 was provided




**RIGHT** The evolution of the F-15 design is shown in this McAir schematic, with major changes coming in 1979 and 1985, in the form of the F-15C/D and MSIP respectively. The F-15E would be born in 1987. *(Boeing)*

**CENTRE** Two 53rd TFS 'Tigers' F-15Cs taxi out for take-off at Bodø, Norway. The 'Tigers' deployed to Bodø for a one-off TDY (temporary duty assignment) to fly cover for a NATO Naval Task Force operating off the Norwegian coast, intercepting Soviet Naval Aviation Tu-95 'Bear-Ds' and 'Es' shadowing the NATO warships. The Squadron served TDY because the aircraft carrier that would normally have provided air cover was engaged with Libyan forces in the Gulf of Sidra. Aircraft 79-073 was delivered to Bitburg on 5 May 1982 and spent 11 years there before being transferred to the 1st FS, 325th FW at Tyndall AFB, Florida, as a training jet. *(USAF)*

with a programmable signal processor (PSP), enabling the upgrading or modification of the radar's search and tracking logic by means of changing a computer tape. Additionally the radar data processor (radar's internal computer) memory was increased from 24K to 96K. This allowed the radar to 'remember' the location and vector of one target while the pilot locked up another, and could transfer the lock back and forth between two targets.

Behind the radar, the CP-1075 CC was also significantly upgraded and could be reprogrammed using operational flight program (OFP) updates. The new CC also enabled the addition of an overload warning system (OWS) that gave the pilot an aural tone to indicate how close to maximum g he was pulling. The more robust F-15C airframe was rated to 9g,

**RIGHT** At the sound of the horn, the Eagle pilots race to their jets for a Zulu scramble. During the Cold War this scene was repeated frequently to ensure practised readiness of the pilots and ground crews. In this case it takes place at Elmendorf AFB, Alaska, as Major Tom Oberg dashes to his F-15C, which is loaded with two AIM-120 AMRAAM, two AIM-9X and two external fuel tanks. *(USAF)*

**RIGHT The Louisiana ANG's MSIP F-15A Eagles carry 'JZ' tailcodes in reference to the jazz music that is synonymous with New Orleans. The lack of teardrop ICS fairings above and below the nose is one of the few external differences that help distinguish the MSIP A-model from the MSIP C-model. This Eagle is configured as a target tow for gunnery practice.** *(Gary Klett via Steve Davies)*

**BELOW McDonnell Douglas saw the potential for the F-15 design as a true multi-role fighter – able to fight its way into and out of the target area, as this artist's rendition shows.** *(Boeing via Steve Davies)*

compared to 7.33g of the A/B model. Other improvements included jam-resistant radios and general avionics improvements.

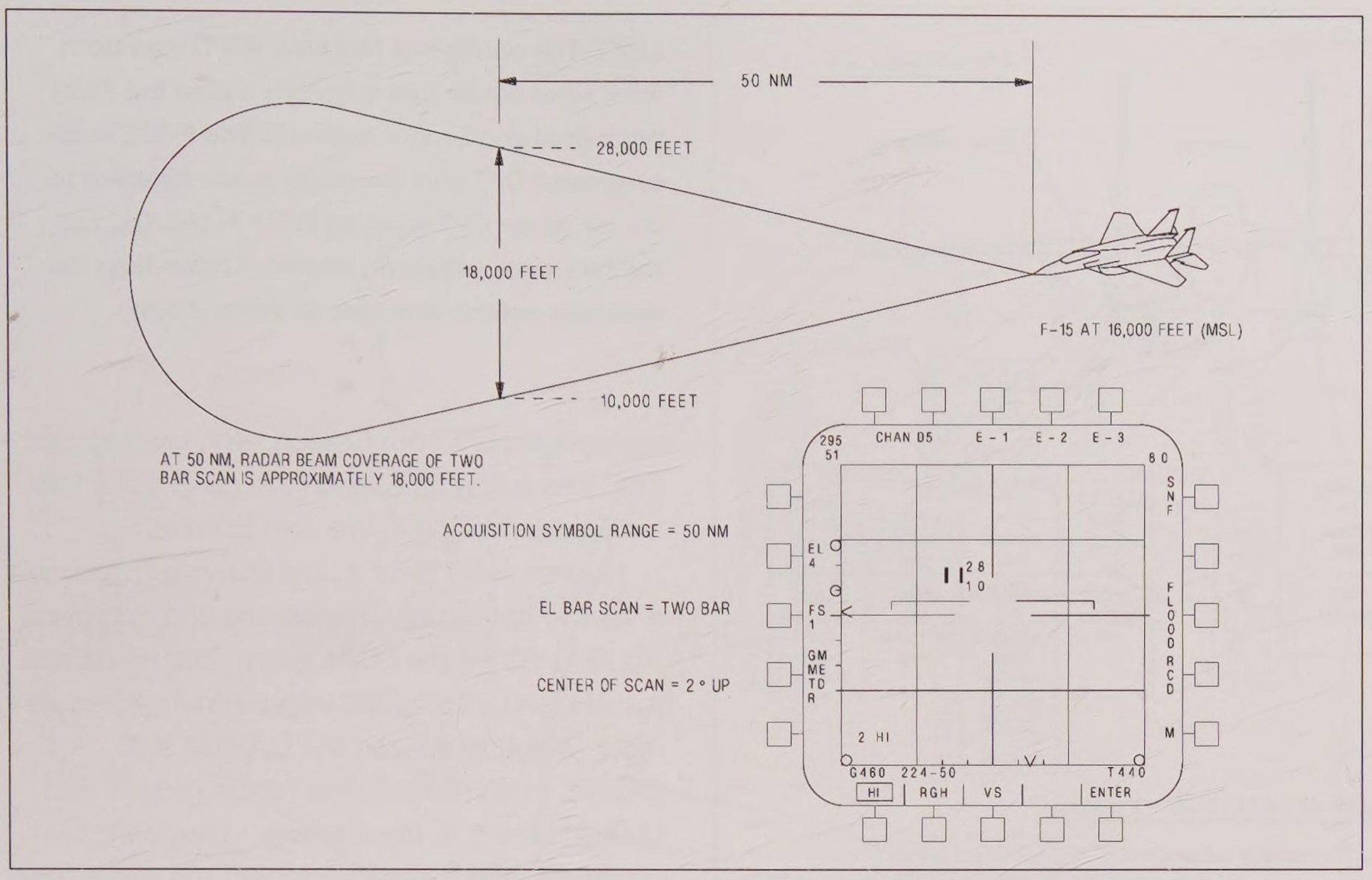
Many of the improvements to the F-15C/D came courtesy of a separate and ongoing effort known as the Multi-Stage Improvement Program (MSIP). MSIP, which actually developed in two phases – MSIP and MSIP II – did many things, but broadly speaking it brought the Eagle into the digital age, to include a MIL-STD 1760 data bus, and significantly improved its lethality.

MSIP focused on several key areas: the CC, the data bus and its associated cabling, a new armament control set, HOTAS improvements, and modifications to allow provision for the future addition of a data link. MSIP was installed in kit form on some F-15As, and McAir delivered F-15C/Ds with MSIP already installed. The multi-stage nature of MSIP meant that other improvements were made later in time (see *Eagle improvements*, page 34).

While the 18th TFW was the first USAF wing to be equipped with the improved Eagle, in Europe the 32nd TFS at Soesteburg AB, the Netherlands, was the first unit to upgrade to the F-15C, the first three jets arriving on 13 June 1980. The 36th TFW's 'Bulldogs' quickly followed suit, beginning conversion in December 1980, the last A-model departing Bitburg in January 1981. Stateside, the 94th 'Hat in the Ring' Squadron was the first TAC unit to receive the C-model, attaining initial operating capability on 4 November 1981.

## F-15E – the Strike Eagle

As contentious as it had been throughout its development, the F-15A/B had been developed from the outset to not only carry four AIM-7 and four AIM-9 missiles as an air

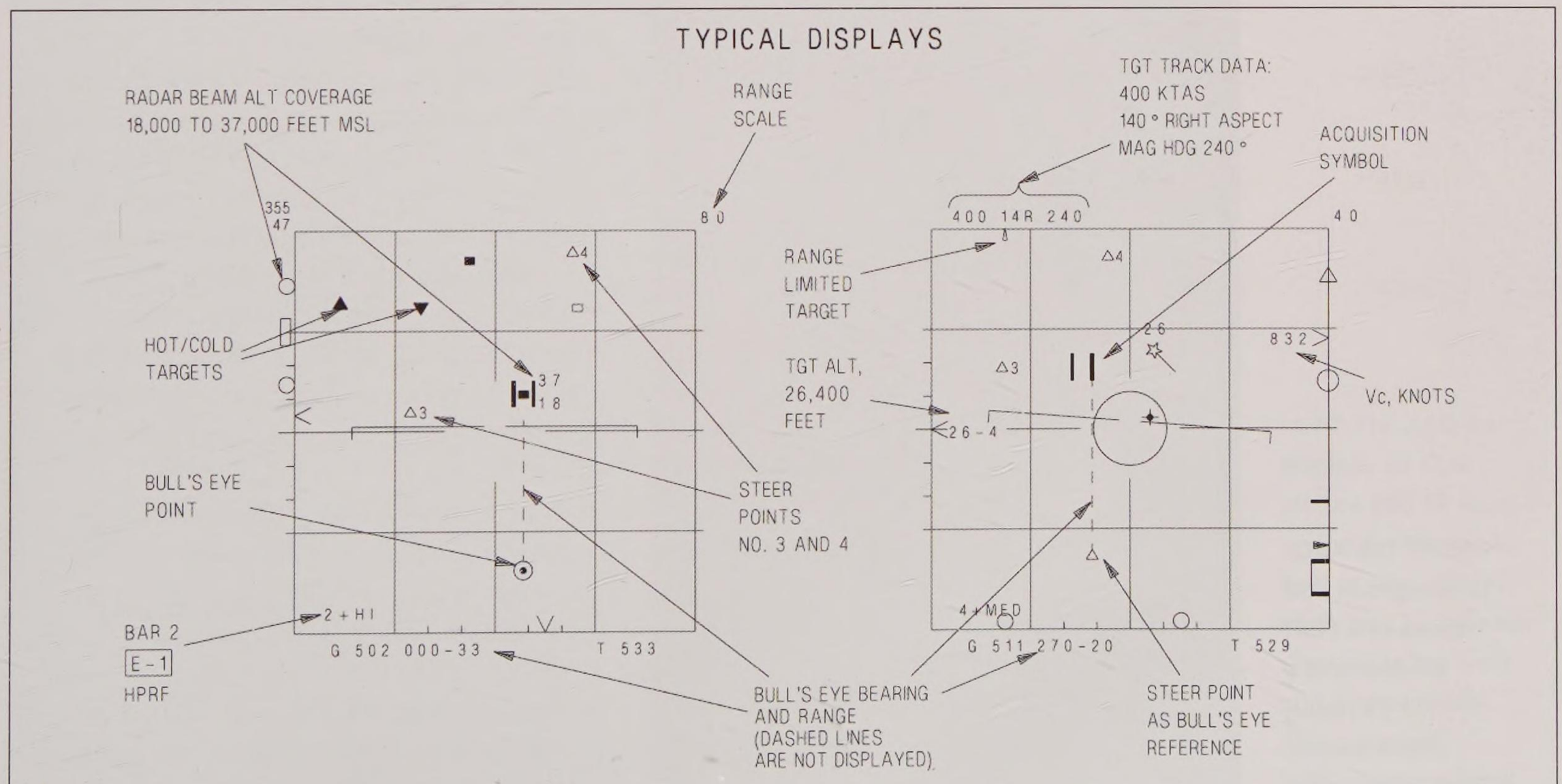


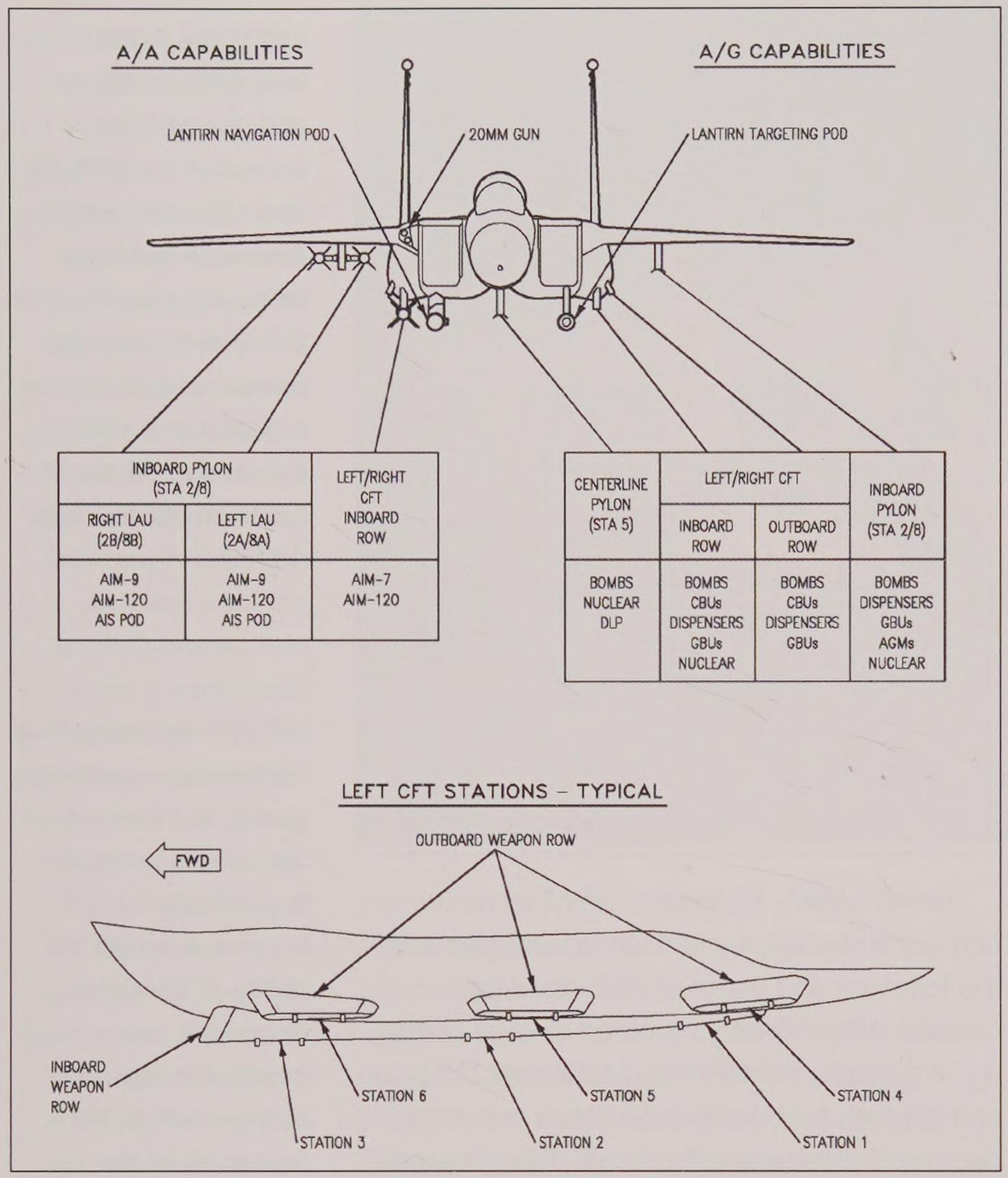

**LEFT The F-15E was to be equipped with the APG-70, a variant of the APG-63. The APG-70's radar coverage and scan limits were identical to the APG-63, and the newer radar was soon installed in F-15C/Ds coming off the St Louis production line.** *(USAF)*

superiority standard load, but also to be able to carry some 15,000lb of bombs in the air-to-ground role, on 18 stations littered about the airframe and wings. With its APG-63 radar, VSD, HUD and central computer working in unison, it would also be able to maximise accuracy against ground targets. Moreover, the Eagle had been wired to support the latest generation of guided air-to-ground bombs and missiles, still without losing any air-to-air capability.

'Strike Eagle', a combination of clever corporate strategy by McDonnell Douglas and the foresight and vision of TAC commander General Wilbur Creech, took advantage of the ageing status of the F-111. McDonnell Douglas and Hughes had recognised that a two-seat, dedicated strike version of the F-15 could well be a purchase in which the USAF would show great interest, and set about developing this concept. The consortium received positive

**BELOW As computing technology – and the power and memory of the central computer in particular – improved, so did the ability of the radar to provide ever-increasing amounts of information. Here, just some of the information generated by the APG-70 and CC is explained.** *(USAF)*





**RIGHT The AAQ-13 navigation pod features a FLIR window and a TF radar.** *(Steve Davies/ FJPhotography.com)*

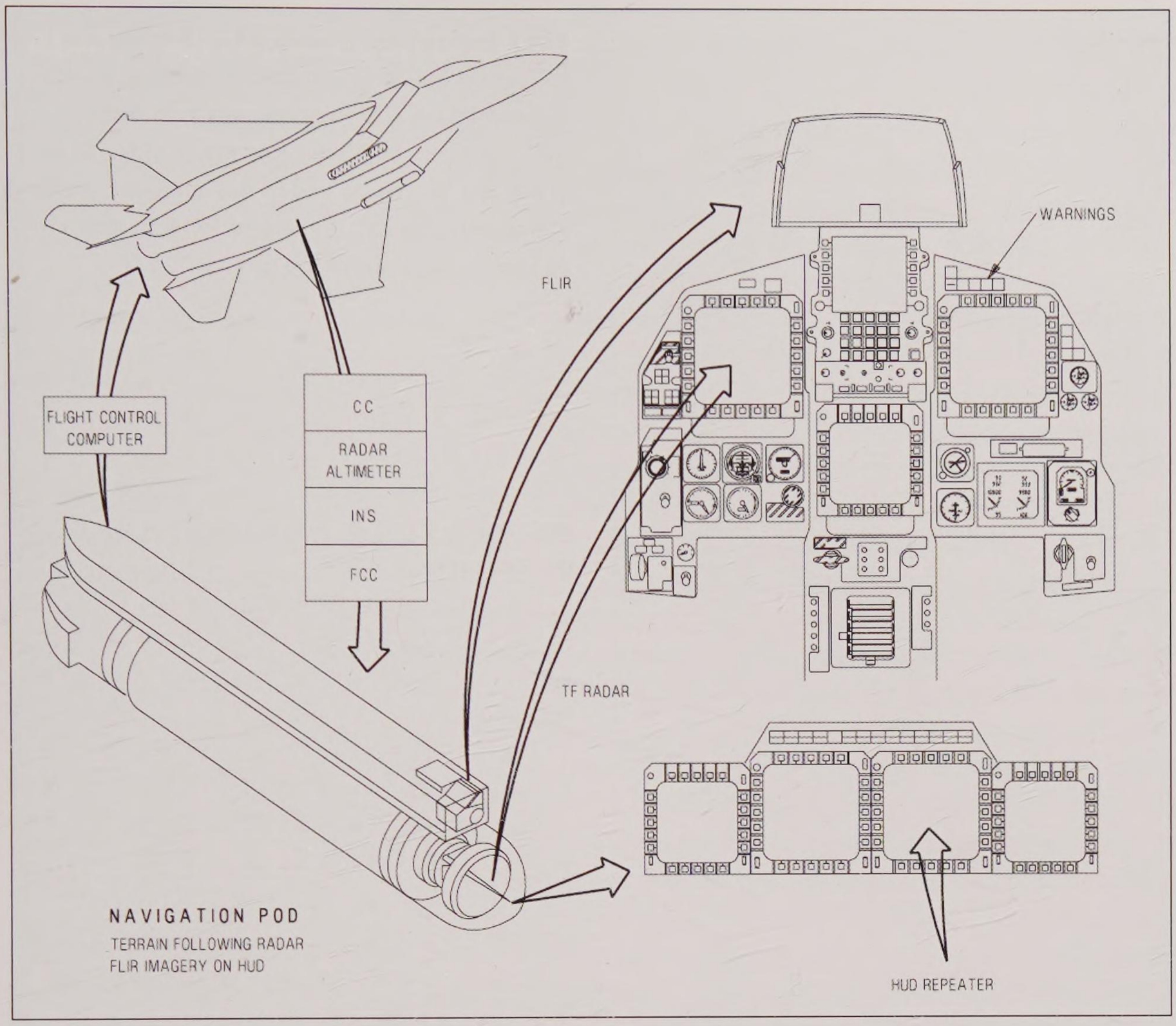
**LEFT The conformal fuel tank (CFT) was born from what McAir had originally called the FAST pack (fuel and sensor tactical). The F-15E's air-to-ground CFT was internally much different to the air-to-air CFT used by MSIP F-15C/Ds, but the two were externally identical other than the weapons pylons attached to them.** *(USAF)*

encouragement from Creech, who worried that TAC was losing its edge in the deep strike role – a crucial mission in Western Europe.

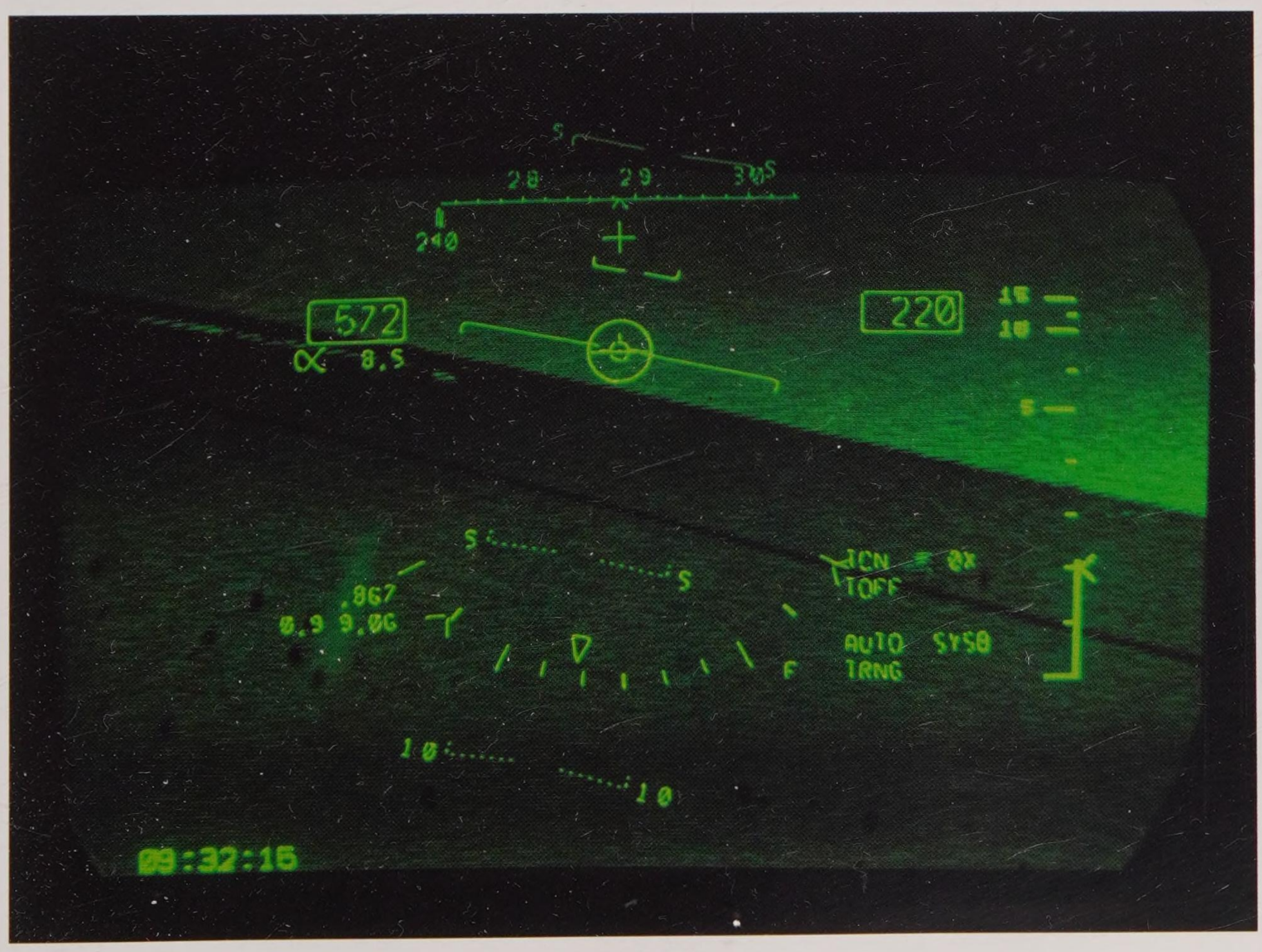
Hughes went back to the drawing board with a view to completely overhauling and improving the APG-63 for the Strike Eagle. The result was the APG-70 – complete with synthetic aperture radar, which measured the Doppler shift created when radar waves hit the ground and bounced back to the antenna. Using complex computer algorithms to establish the movement of the aircraft relative to the ground, the radar interpreted these shifts and translated them into a top-down picture in the two-place cockpit. The resulting image gave a very clear view of the ground, which, when viewed by the pilot or Weapons Systems Officer, looked very similar to a bird's-eye view of the target area. This process became known as 'patch mapping' and could be achieved down to a resolution of 0.67 of a nautical mile. The APG-70 (minus the synthetic aperture mapping mode) was later installed in some F-15Cs.

Two other key components were integrated into the Strike Eagle: air-to-ground optimised conformal fuel tanks and LANTIRN (low-altitude navigation targeting infrared for night). The United States Air Force signed a contract with Martin Marietta to produce LANTIRN, a combination of forward-looking infrared optics and terrain-following (TF) radar, in two underslung pods mounted below the engine nacelles. LANTIRN reached operational status in 1987.

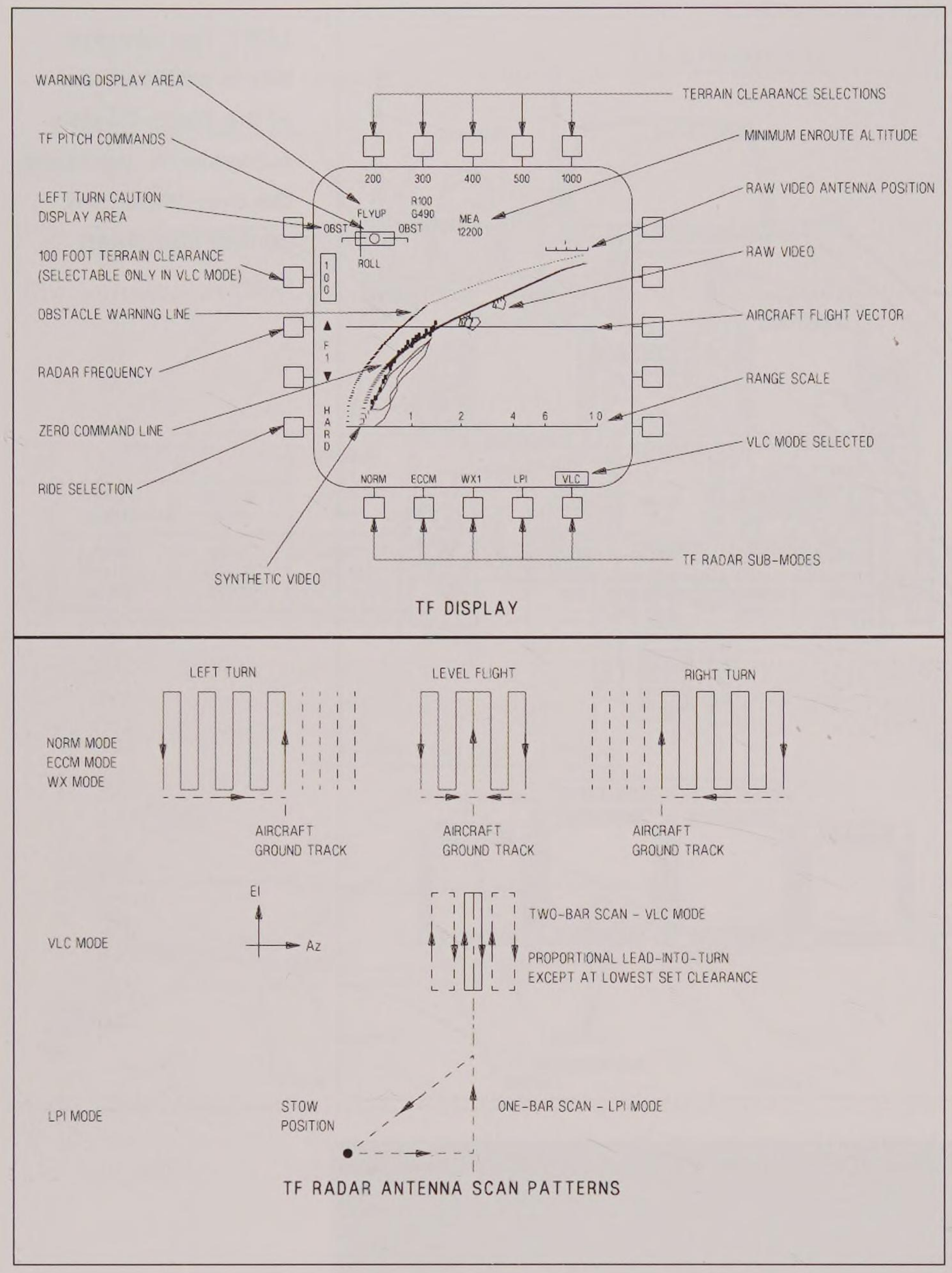
Designated the AAQ-13 Navigation Pod and AAQ-14 Target Pod (TP), each pod was attached via two mounted lugs and simple electrical terminals. The 'Nav Pod' was mounted under the right engine nacelle and housed a FLIR (forward-looking infrared) sensor and TF radar and was primarily used by the pilot to allow hands-off low altitude flying in all




**LEFT The nav pod ties in with various of the Strike Eagle's subsystems, including the ever-important central computer.** *(USAF)*




**LEFT The AAQ-13 displays its FLIR picture and TF cues on the F-15E's wide field of view (WFOV) HUD, and on repeater displays in the front and rear cockpits.** *(Steve Davies/ FJPhotography.com)*




**LEFT Meanwhile, the AAQ-14's TF scans the terrain ahead using a variety of patterns (mode dependent, as shown here), and then displays both synthetic and raw radar return video to the crew. The TF can be tied to the autopilot, giving the crew hands-off, automatic TF flight down to as low as 100ft above the ground.** *(USAF)*

**BELOW The second part of the LANTIRN pairing is the AAQ-14 target pod, although this has today been largely superseded by the more capable AAQ-28 LITENING II and AAQ-33 Sniper pods.** *(Steve Davies/FJPhotography.com)*

weather, night or day. The FLIR sensor looked ahead of the aircraft and could display the resulting image on to the pilot's Kaiser WFOV (wide field of view) HUD. The TF looked ahead and slightly to either side of the jet to detect obstacles and terrain.

Mounted on the left pylon was the TP. Used by the WSO to identify and designate targets when weather conditions permitted, it could be tied to the radar or manipulated independently. It had three selectable fields of view and housed a laser designator with which to guide laser-guided bombs (LGBs) on to the target. The WSO then had to find his target in the TP, put the cross hairs over it and press a button to commit the pod to tracking it. Several tracking options were available, all of which permitted the WSO to keep one eye on other systems during the course of the attack run, something that F-111F WSOs were never able to do. In the years that followed, the AAQ-14 would be replaced by the AAQ-28 LITENING II and AAQ-33 Sniper target pods, but the AAQ-13 would remain a staple Strike Eagle accessory.

McAir developed new manufacturing techniques to give the F-15E a 16,000-hour fatigue life, the forward avionics bays were redesigned (along with changes to the electrical system that supplied them), and the ammunition carriage space for the M-61A1 was reduced in size to make way for additional avionics. The engine bays were redesigned to allow commonality in plumbing and installation of either P&W or GE engines, and the tail hook was modified to accommodate a heavier anticipated landing weight. These modifications permitted a new sustained 9g capability, but compelled the installation of a new landing gear and wheels in order to allow the jet to operate safely at higher gross weight. In all, the F-15E weighed in at just under 16,000lb heavier than the F-15C and had a maximum take-off weight

## ASAT – ANTI-SATELLITE EAGLE

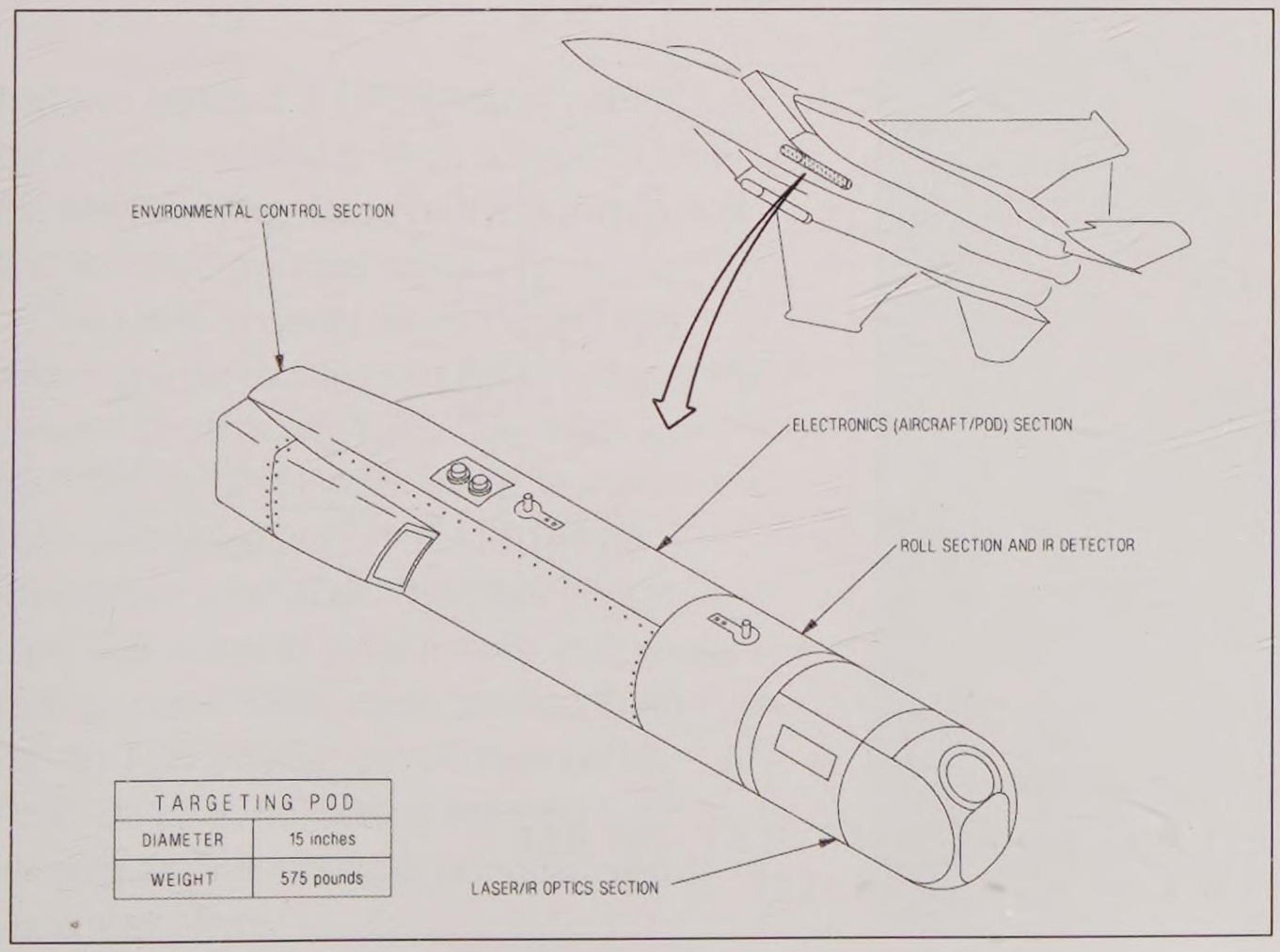
The Vought ASM-135A ASAT was a kludge of various components to make an air-launched, IR-guided 'hittile' (meaning it had to actually hit the target satellite to destroy it – the ASAT carried no warhead). The first stage was that of a Boeing AGM-69 SRAM-A (short-range attack missile – to be used by SAC bombers to suppress enemy SAMs on ingress). To this was bolted a variant of the Altair III rocket, upon which was mounted a small IR-guided 'homing kinetic kill vehicle', designed to zero in on the heat source of an oncoming satellite and smash into it.

For a successful engagement, the ASAT had to be launched from an extremely high altitude (80,000ft) and high angle (60–65°), exactly on the predicted track of the oncoming satellite. Prior to the satellite's appearing over the horizon, the F-15 would be positioned in a holding pattern along this path by NORAD controllers, using their satellite-tracking data of the target to ensure exact placement. On NORAD's command, the satellite interceptor pilot would head towards the target, accelerate to high Mach and then zoom upwards in a steep climb angle to launch the missile.

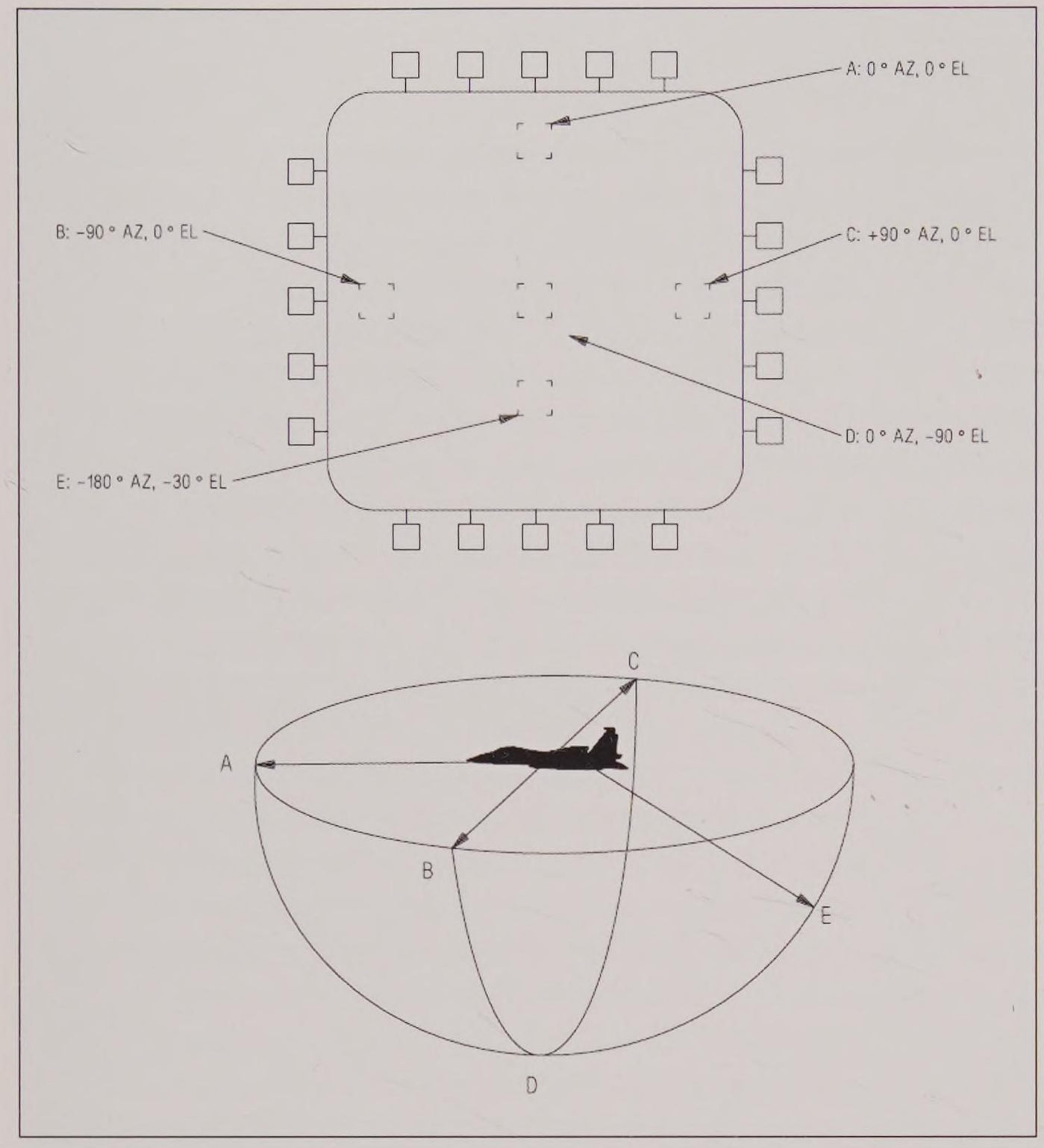
After numerous 'captive carry' and 'zoom climb' tests by two different 6512th Test Squadron F-15As, the first launch of the ASM-135A was made in January 1984, with the missile aimed at a 'pre-determined point in space'. This was followed, over the course of the next year and a half, by three launches with the IR-seeker locked on to the IR-signature of a 'celestial IR source' (more commonly known as a 'star'). Finally, on 13 September 1985, F-15A 77-0084 was used for the first and only launch against an orbiting satellite, the Solwind P78-1. This 2,000lb, 11ft gamma-ray spectrometer satellite had been launched in February 1979 and by late 1985 had officially outlived its useful life, although it was still sending data from its circular polar orbit. Since Soviet reconnaissance, maritime surveillance and electronic intelligence (ELINT) satellites were normally placed in polar orbits, Solwind P78-1 made a perfect target simulator.

The launch went flawlessly, and 320 miles above the earth the speeding satellite – whistling along at 17,000mph – was impacted by the 11,000mph ASAT, the combined velocities smashing the Solwind satellite into smithereens. But the celebrations were soon drowned out by the indignant outcry of the solar scientists still receiving and using the data from the satellite and by arms control activists. The latter soon convinced Congress that the test was in violation of the recently signed US–USSR ban against the testing of or use of weapons in space and Congress cut the funding to the programme, the USAF officially terminating it in 1986.

**BELOW The target pod is slung under the port (left) intake and features a rotating head that incorporates the optics, laser range finder and designator, and (in the case of the AAQ-28 and AAQ-33) laser spot tracker.** *(USAF)*




**BELOW The video from the target pod is presented to the pilot and WSO on any of the cockpit multi-purpose displays (of which there are three in the front cockpit, and four in the rear cockpit).** *(Steve Davies/FJPhotography.com)*

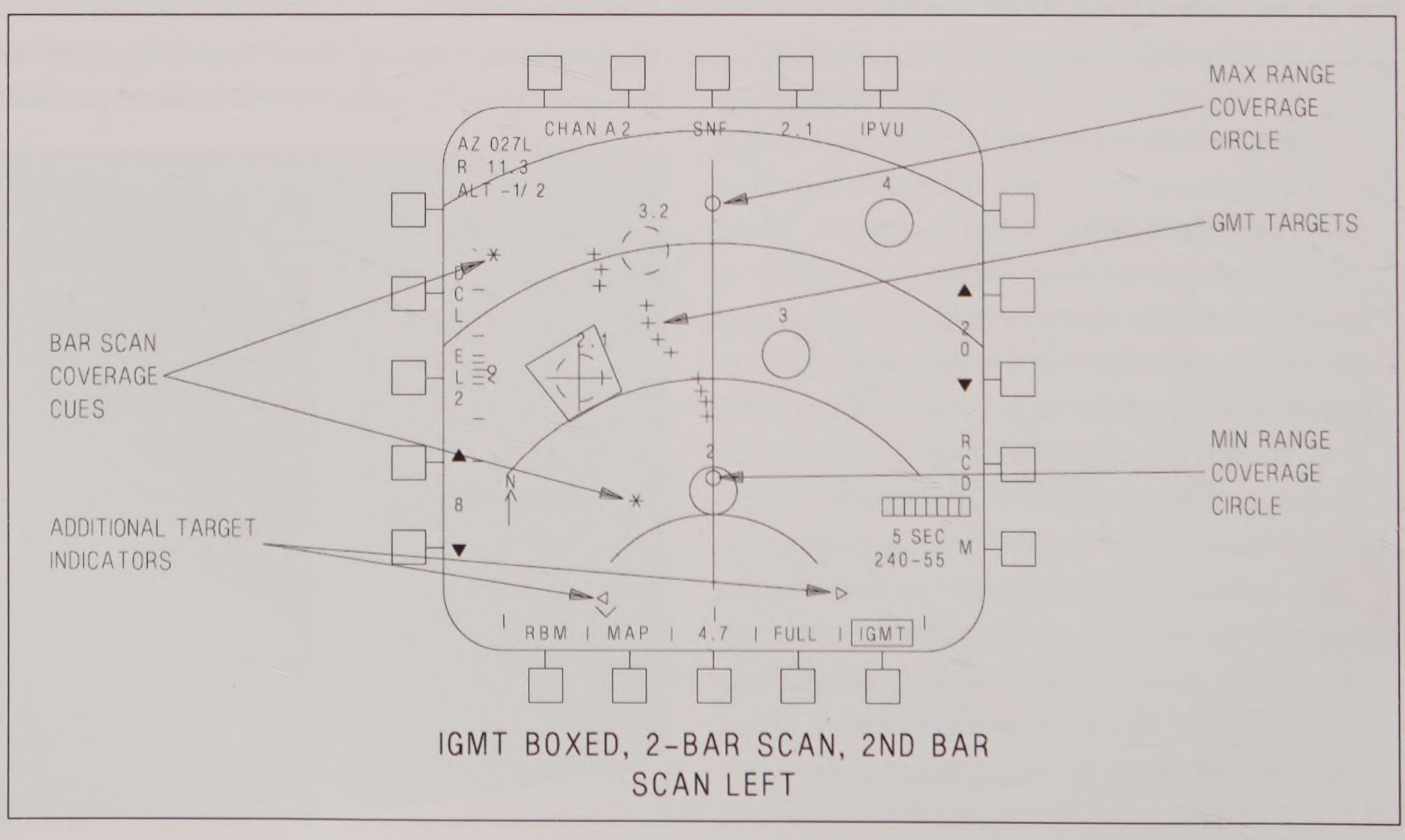



**LEFT In order to orient the weapons system officer or pilot as to the direction the target pod is pointing, a dashed box is displayed relative to its top-down viewing angle.** *(USAF)*

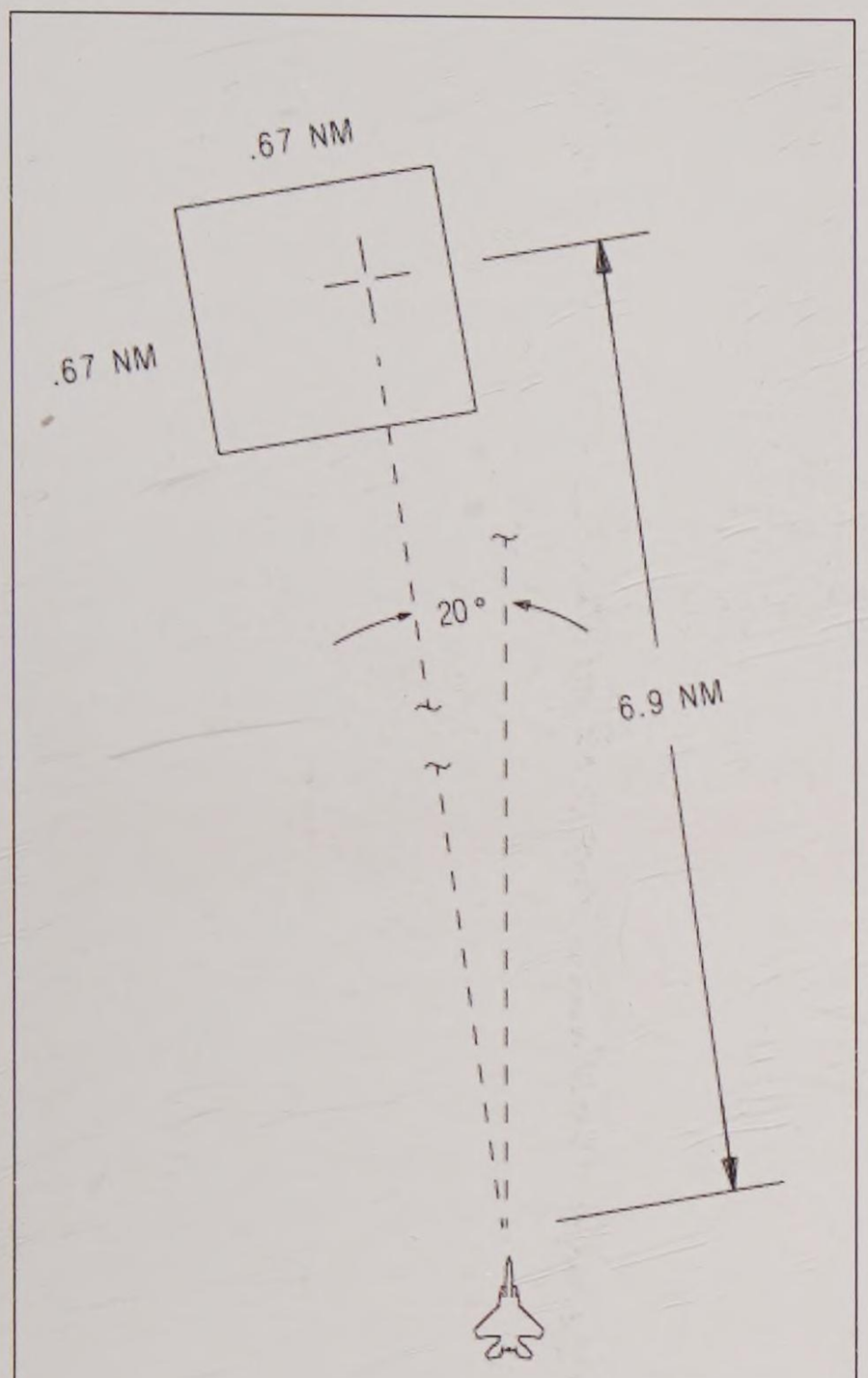
**BELOW The target pod's dashed box is seen here at the very top of the display, indicating that the pod is facing directly ahead.** *(Steve Davies/ FJPhotography.com)*

of 81,000lb. In USAF service the aircraft is powered by either the F100-PW-220 or the F100-PW-229 (see chapter four), the latter generating 29,500lb of thrust in afterburner.

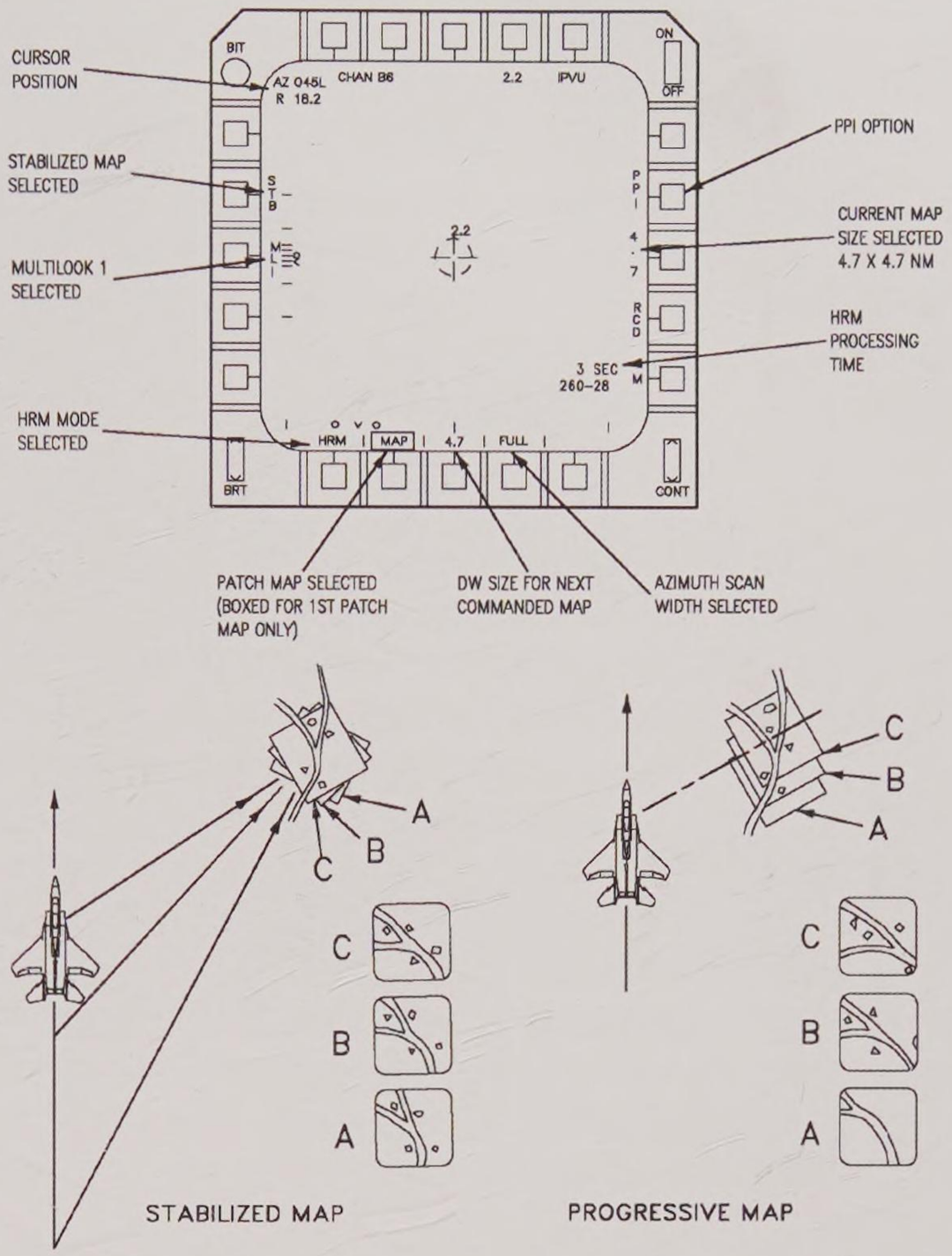
The two-man cockpit was considerably updated, with an emphasis being placed on interoperability – the ability of each crew member to perform almost any function necessary to get the mission done. The front cockpit featured two monochrome multi-purpose displays (MPDs) and one colour MPD (MPCD). The rear cockpit housed two MPDs




**RIGHT The APG-70 in the F-15E features a range of air-to-ground modes. Here, IGMT (interleaved ground moving target) allows the crew to map the terrain and use the radar's Doppler capabilities to identify moving ground targets.** *(USAF)*




**ABOVE The Strike Eagle's ability to create 'patch maps' or high resolution maps (HRM) of target areas is noteworthy. Patch mapping cannot place on the aircraft's centreline, but must instead be accomplished either side of the nose.** *(USAF)*




**ABOVE As shown here, patch maps can be stabilised, or built progressively…** *(USAF)*

**BELOW Equipped with a two-person crew, a powerful radar and LANTIRN, the F-15E is a force to be reckoned with. Here a 335th FS Strike Eagle flies clean of air-to-ground stores over North Carolina.** *(Steve Davies/FJPhotography.com)*

and two MPCDs. A UFC (upfront control panel) was installed in each cockpit to allow the crew to enter data into the powerful and sophisticated avionics suite.

The USAF ordered the F-15E in 1984 following a six-month competition against the General Dynamics F-16XL. July 1985 saw 86-0183, the first F-15E, make its maiden flight, and two other F-15Es (-0184 and -0185) flew soon after. The 33rd TFW at Eglin AFB received three F-15Es in August 1986 to begin USAF trials, culminating in the 4th TFW at Seymour Johnson AFB, North Carolina, converting from the F-4E to become the first operational F-15E wing in December 1988.

## OTHER EAGLES

### Streak Eagle (AF72-0119)

0119 was used for two weeks as of 16 January 1975 to establish the full performance capabilities of the F-15 in a controlled and instrumented environment. Three USAF F-15 pilots flew the jet to very precise parameters during this time, thereby achieving several speed and climb world records. The aircraft was heavily modified to reduce weight as much as possible. Amongst the list of items removed were a generator, a speed brake and flap actuators, utility hydraulic system, non-critical cockpit displays and radios, landing and taxi lights, and radar/associated LRUs. The aircraft was a Cat II airframe, and was already 800lb lighter than Cat I aircraft prior to any modifications. In all the jet was reduced to 1,800lb less than other Block 6 aircraft. The programme cost was $2.1million.

**BELOW The F-15 STOL/MT demonstrator was used to evaluate thrust vectoring and enhanced manoeuvrability. Using 70291 – the second two-seat F-15 – as the test bed, the aircraft featured forward canards and thrust vector nozzles that could be deflected by 20°.** *(USAF)*

### F-15S/MTD (AF71-0290)

This was a $117.8 million programme awarded to McAir by the USAF in 1984. The total contract cost eventually reached $272 million, and from it was born the F-15 Short Take-Off and Landing/Maneuvering Technology Demonstrator (F-15S/MTD). The basis for the contract was to test emerging technologies for suitability to the USAF's Advanced Tactical Fighter – the competition between the YF-23 and YF-22, the latter of which emerged victorious. Controllable foreplanes were added, so too were F-15E cockpit switches and displays, F-15E landing gear, and provisions for the APG-70 and LANTIRN pods. Most importantly, however, two dimensional thrust-vectoring nozzles were added to modified PW-220 engines. These nozzles were made from titanium and carbon-fibre, and were able to enhance manoeuvring, take-off and landing performance. They could redirect thrust longitudinally by 20° up and down, could provide full reverse thrust on landing, and could provide limited amounts of braking thrust whilst airborne via use of louvres just in front of the divergent/convergent nozzles. 350 hours of ground testing was performed by Pratt & Whitney, revealing that the engines and nozzles were capable and relatively trouble-free.

To make use of the advanced flying control surfaces and systems, a fly-by-wire control system was used to operate the four control channels. The addition of the foreplanes had meant an expanded flight envelope for the NF-15B (as it was known by McAir), and the jet eventually demonstrated an increased air combat capability in several areas: 50% increase in roll rate, 30% increase in pitch rate, decreased landing rolls, decreased take-off runs and so on.

In addition to the raw performance capabilities that saw the NF-15B pushing the flight envelope, interesting technological innovations were also being tested. One such innovation involved using the AAQ-13 LANTIRN navigation pod and APG-70 in concert to provide steering cues to land at an unplanned alternate airfield. The system was demonstrated to allow the aircrew to patch map an airfield and have the APG-70 automatically provide glide scope steering for a perfect approach. All the while the pilot referenced the navigation pod to visually confirm what his computers were telling him. The programme ended in 1991, and paved the way for 0291's next testing assignment – Advanced Control Technology for Integrated Vehicles (ACTIVE).

ACTIVE was a programme started in 1996 based on a similar premise to the S/MTD venture: to test and develop technologies for operational use in the next generation

of airframes. ACTIVE saw NASA, P&W, USAF and McAir installing a revised thrust-vectoring system on to two PW-229s. Aside from the different engines, the other main difference was the multi-directional nozzles – ±20° in any direction (known as pitch/yaw balance beam nozzles). These beam nozzles lacked a braking thrust/thrust reversing capability and the use of vectoring at high Mach numbers (Mach 2). In this configuration, the aircraft was designated NF-15B ACTIVE.

## NASA Eagles

NASA has operated a number of F-15s: AF71-0281 was used in December 1975 to test the thermal tiles used by the Space Shuttle; it was handed back to the USAF in 1983. F-15B AF74-0141 was used from 1994 as the Aerodynamic Flight Facility. Designated NASA 836, it was used to carry the Flight Test Fixture (FTF) on the centre pylon. The FTF houses research systems and materials for testing, a good example of which is the X-33 thermal protection system. Tested during FTF II, the system calibrated, monitored and instrumented the materials destined for the X-33 at various flight velocities, altitudes, temperatures, aerodynamic loadings etc.

F-15A, NASA 835, was acquired on 5 January 1976, and was operated as the Flight Research Facility. Originally AF71-0287, it was the eighth production F-15A and has been employed in a variety of guises since then – it is probably the hardest worked of all NASA's F-15s. NASA originally used 835 to test and develop future propulsion systems, aerodynamics, integration, control systems, instrumentation development and flight test techniques (amongst other things) in 1976. Then, in 1982, it was used to test DEEC for the F100-PW-220. This new engine demonstrated massive performance increases and went on to be the test bed for the F-100 IPE.

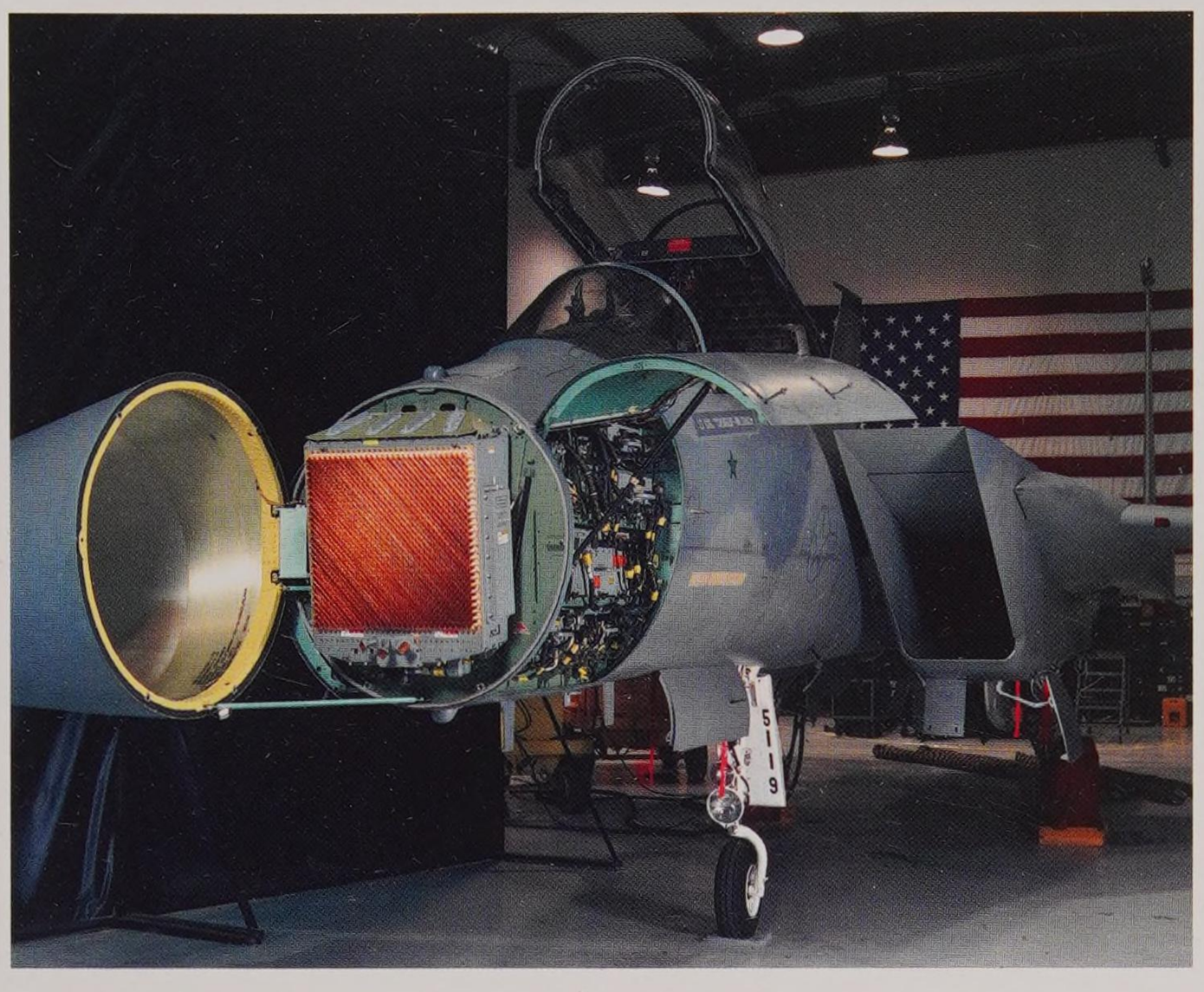
1986 saw it testing the advanced DEEC engine control system (ADECS), a system used to evaluate and control the stall margin of the engine under different operating parameters. Among the list of results were a decrease in fuel consumption by 15% at constant thrust settings, improved rate of climb by 14% and up to 24% increase in acceleration (the DEEC tests had already demonstrated an increase in acceleration by up to 41%). Most importantly, though, no stalls were encountered, not even with the most heavy-handed and aggressive use of thrust and manoeuvre.

Leaving the DEEC theme, NASA 835 then moved on to HIDEC (highly integrated digital electronic control), a system designed to use computers to detect loss of, or degraded use of, control surfaces. It would then reconfigure the remaining control surfaces to compensate. Simultaneously, it would alert the pilot to the failure and

**ABOVE NASA's digital electronic engine control tests were part of the F-15 HIDEC programme. It tested DEEC controls and evaluated improvements brought about to climb performance, fuel savings and optimisation of engine thrust.** *(NASA)*

generate a new, real-time flight envelope to help the pilot keep the aircraft flying. 835 later tested and demonstrated the self-repairing flight control system (SRFCS) in 1989 – a similar programme to NASA's HIDEC, but one which also offered analysis of failures other than those of the flight control surfaces. Electrics, hydraulics and mechanical systems were all monitored by the SRFCS, which would then make the changes necessary to reconfigure failed systems and keep the jet flying. 1990 saw NASA's workhorse become involved in the Performance Seeking Control (PCS) programme, designed to optimise engine performance and ensure safe operation of the engines through digital monitoring of failures and digital control of inlets, nozzles and flight controls.

NASA 835 ended her career with NASA flying the PCA (Propulsion Controlled Aircraft). A series of crashes caused by loss of flight controls had prompted NASA to begin a programme to determine whether a system could be developed to maintain control of an aircraft by simply altering thrust settings on a single engine. Initial results showed that it was certainly possible to maintain control in pitch with one engine, though asymmetric application of thrust from two engines was necessary to change heading and induce roll. Dryden and McAir took initial results, ran simulations and added a simple device to the cockpit: a two-thumbwheel control panel – one thumbwheel for required aircraft flight path, the other for bank angle. Subsequently the pilot used the thumbwheels to 'fly' the aircraft, which in turn controlled engine thrust via computer algorithms put together by NASA and McAir. The aircraft was flown down to less that 10ft above the runway at 150–190 KIAS using these thumbwheels, and successful, hands-off landings were made at Edwards AFB, California.



**ABOVE The planar array of the APG-63/APG-70, seen here in the F-15E, is mechanically driven and hydraulically powered. On occasion the hydraulic lines puncture, leading to a stuck radar antenna and what is colloquially known as a 'beak leak'.** *(Steve Davies/ FJPhotography.com)*

## Eagle and Strike Eagle upgrades and improvements

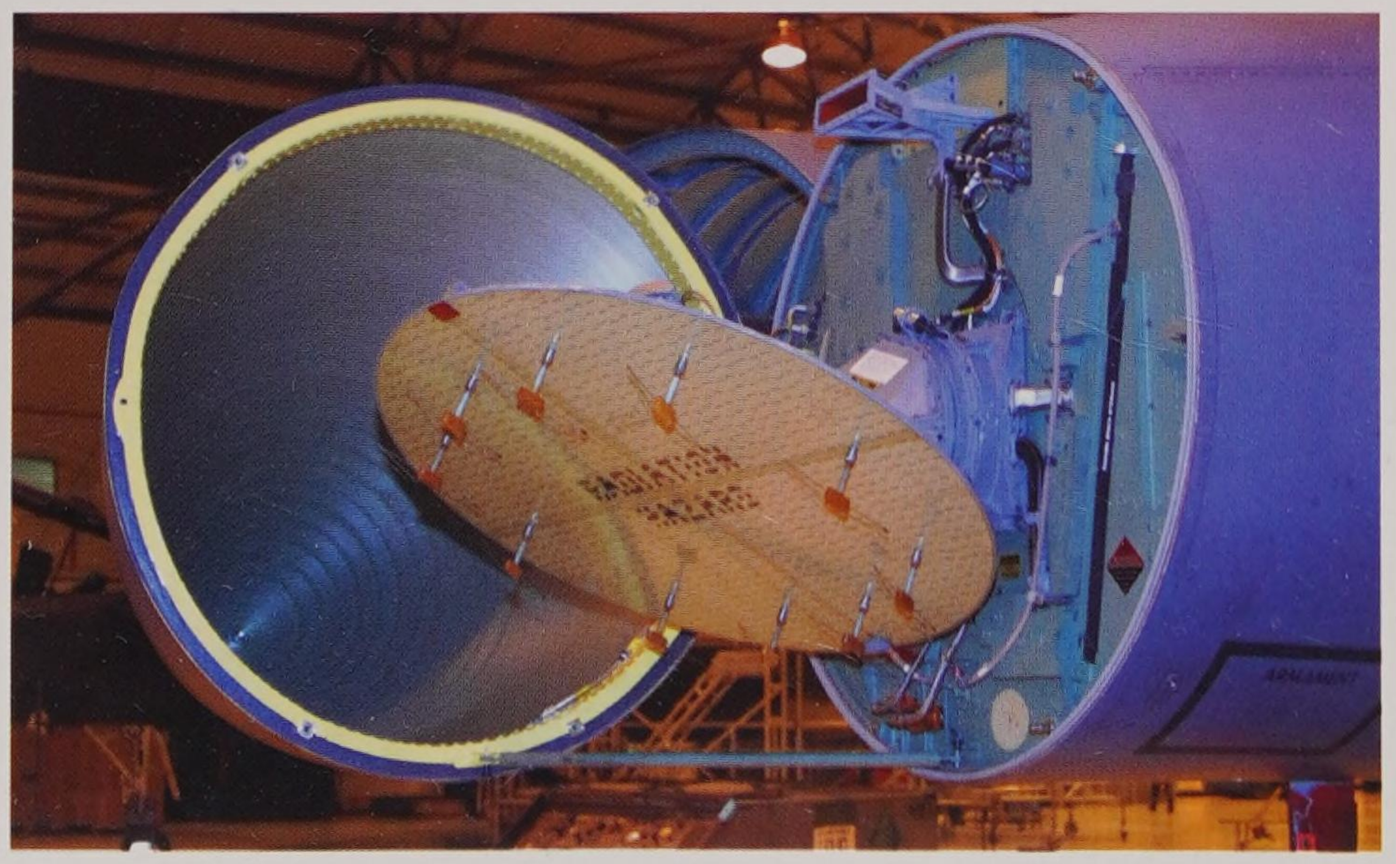
For the F-15A/B/C/D, ongoing MSIP improvements and general upgrades continued over time. The F-15E has also benefited from regular enhancements over the duration of its service life.

The software that sits at the heart of the Eagle and Strike Eagle's CC is upgraded as tweaks are made and new capabilities are added; this operational flight programme (OFP) allows software upgrades to support new hardware installations. OFP is the cornerstone that will allow the US Air Force to keep the F-15 in service beyond 2030, enabling as it does avionics modernisation.

The version of OFP in use on each jet will quickly allow a crew to determine what capabilities the aircraft has. OFP versions are typically characterised as 'suites'. OFP suites are common to the whole Eagle family, and an 'E' suffix is given to those upgrades appropriate to the Strike Eagle (*ie* Suite 4E) and C for the F-15C. As of late 2012, Suites 8E and 7C were in testing. OFP suites enable hardware enhancements – the addition of a satellite radio and the joint helmet-mounted cueing system (JHMCS), for example – and software enhancements.

Over time the F-15C has been equipped with several different radars, all based on the APG-63. These include the APG-70, APG-63(V)1 and APG-63(V)2. For evaluation purposes, the 3rd Wing, Elmendorf AFB, Alaska, operated Eagles with the APG-63(V)2 active electronically-scanned array (AESA) radar until the unit was deactivated in May 2010. The wing's two squadrons each operated a mix of (V)1 and (V)2 radar jets on a ratio of about 2:1 to enhance flexibility. When paired with Fighter Data Link (FDL), this enables a flight leader to serve as the 'mother ship' with an extremely long-range search and feed the information to the rest of his formation. FDL was a follow-on to the Multi Information Distribution System (MIDS) of the mid-1990s and finally reached the Eagle community in 2004. It uses the MPCD to present a top-down digital picture of the battlefield.

The results of the 3rd Wing's light grey squadrons also aided in the creation of the APG-63(V)3 AESA radar. The radar was installed in F-15Cs from 2006 onwards. The APG-63(V)3 increases pilot effectiveness through utilisation of its beam-steering technology and long-range detection and tracking. Its flexibility and the ability to



**LEFT The advent of AESA radar technologies has taken the Eagle to the next stage in capability. While the AESA APG-63(V)2 (pictured) was flown by a single squadron of Eagles, the APG-63(V)3 is being rolled out to the Eagle fleet in larger numbers.** *(Boeing)*

operate in both search and multi-track modes simultaneously enables far better situational awareness (SA), and its simultaneous multi-weapon support – a major force multiplier – and superior detection and breakout ranges against targets (including those that are small or stealthy) is a major advantage.

The Eagle's inertial navigation system (INS) has been upgraded to a ring laser gyro INS, and a global positioning system known as embedded GPS INS (EGI) has subsequently been installed. 2002 saw the installation of the Fighter Data Link, a data-sharing device that enhanced situational awareness by an order of magnitude.

From 2005 the first Eagle units started receiving the joint helmet-mounted cueing system (JHMCS). The F-15E community received the helmet in August 2010. It allows the Eagle's pilot to cue the high off-bore sight (HOBS) seeker head of the AIM-9X visually, and is crucial if the new AIM-9X Sidewinder's capabilities are to be fully exploited. For the Strike Eagle, which is yet to receive the AIM-9X, the helmet offers significant situational awareness and weapons employment improvements in both air-to-ground and air-to-air operations.

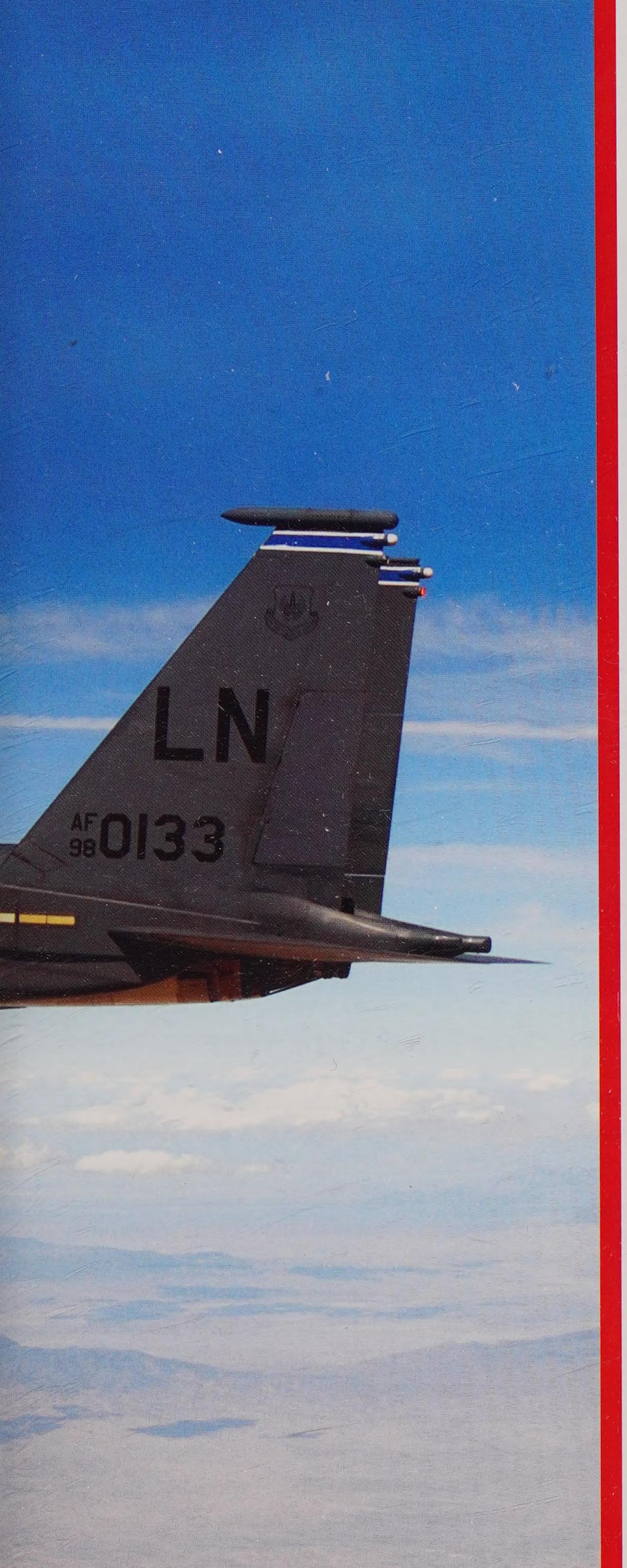
For the Strike Eagle, the F-15E Radar Modernisation Program (RMP) saw developmental flight testing begin in January 2011 for the APG-82(V)1 (originally designated APG-63(V)4). According to official Air Force documents, by replacing the ageing APG-70 on 222 F-15Es 'the RMP APG-82(V)1 design leverages capabilities from currently fielded AESA radar systems. The APG 82(V)1 antenna and power supply are currently in use on the F-15C APG-63(V)3 program, and the radar receiver/exciter and Common Integrated Sensor Processor are based on F/A-18E/F APG-79 AESA system.' Low-rate initial production was approved in 2012.

**ABOVE The joint helmet-mounted cueing system (JHMCS) is a sight that provides similar information to the HUD, but projects it on to the inside of the visor in front of the right eye. JHMCS can also be used to designate off-boresight targets for the AIM-9X Sidewinder.** *(Ben Cook)*

## Engine upgrades

The new F100-PW-220 engine was installed in F-15Cs AF 85-0095 and up, and F-15Ds AF 85-0130 and up. The '220 was much anticipated and provided real improvements in operational capability maintenance, fuel consumption and overall operating cost. The PW-220 actually produces slightly less thrust than the PW-100, developing 23,450lb of augmented thrust (-380lb compared to the PW-100). What makes the engine significantly more attractive, however, is the advantage of full authority digital electronic engine control (DEEC). DEEC has proven to reduce wear and tear on engine components whilst increasing engine performance, fuel consumption and lifespan. It achieves this through digital control laws that constantly monitor a range of operating parameters and makes fine-tuned adjustments to them accordingly. DEEC replaced the PW-100's slower analogue system, which often 'lags' behind pilot's throttle inputs. Testing by the F-15 Combined Test Force commenced in the second quarter of 1985 and ran through until the beginning of the third quarter of 1986.

An upgrade programme commonly referred to as a '-220 equivalent kit', or simply 'E-kit', began in 1997 and is still ongoing today. This takes the F100-PW-100 engine and brings it up to the equivalent specification in thrust and reliability of a production model F100-PW-220 engine.




*Chapter Two*

# The F-15 at war

**The Eagle and Strike Eagle have flown combat operations in a number of theatres of operation, but none more so than in the Middle East. Since the Iraqi invasion of Kuwait in August 1990, the F-15 family has formed the pointy end of a very long spear, killing enemy MiGs in both Iraq and Yugoslavia in the case of the F-15C, and wreaking all kinds of havoc against ground targets in the case of the F-15E.**

**OPPOSITE The heaviest munition in the F-15E arsenal is this, the GBU-28 'bunker buster'. Machined from a 105mm howitzer barrel, the weapon weighs 5,000lb and has been used to strike caves in Afghanistan and underground operations centres in Iraq.** *(USAF)*

**ABOVE The 58th Tactical Fighter Squadron would end the First Gulf War as the leading MiG-killer unit. Stationed at Eglin AFB, Florida, the 'Gorillas' took a mix of MSIP and non-MSIP jets to operation Desert Shield, but by the time the war began on 17 January 1991 its non-MSIP jets had all been swapped out.** *(Steve Davies/FJPhotography.com)*

## The First Gulf War

When Iraq's dictator, Saddam Hussein, invaded neighbouring Kuwait in August 1990, the United States and its coalition allies sprang into action. The West's response came in two phases: a defensive operation – Desert Shield – designed primarily to thwart any attempt by Hussein's forces to roll south into Saudi Arabia, and an offensive operation – Desert Storm – to repel the occupying Iraqi forces from Kuwait.

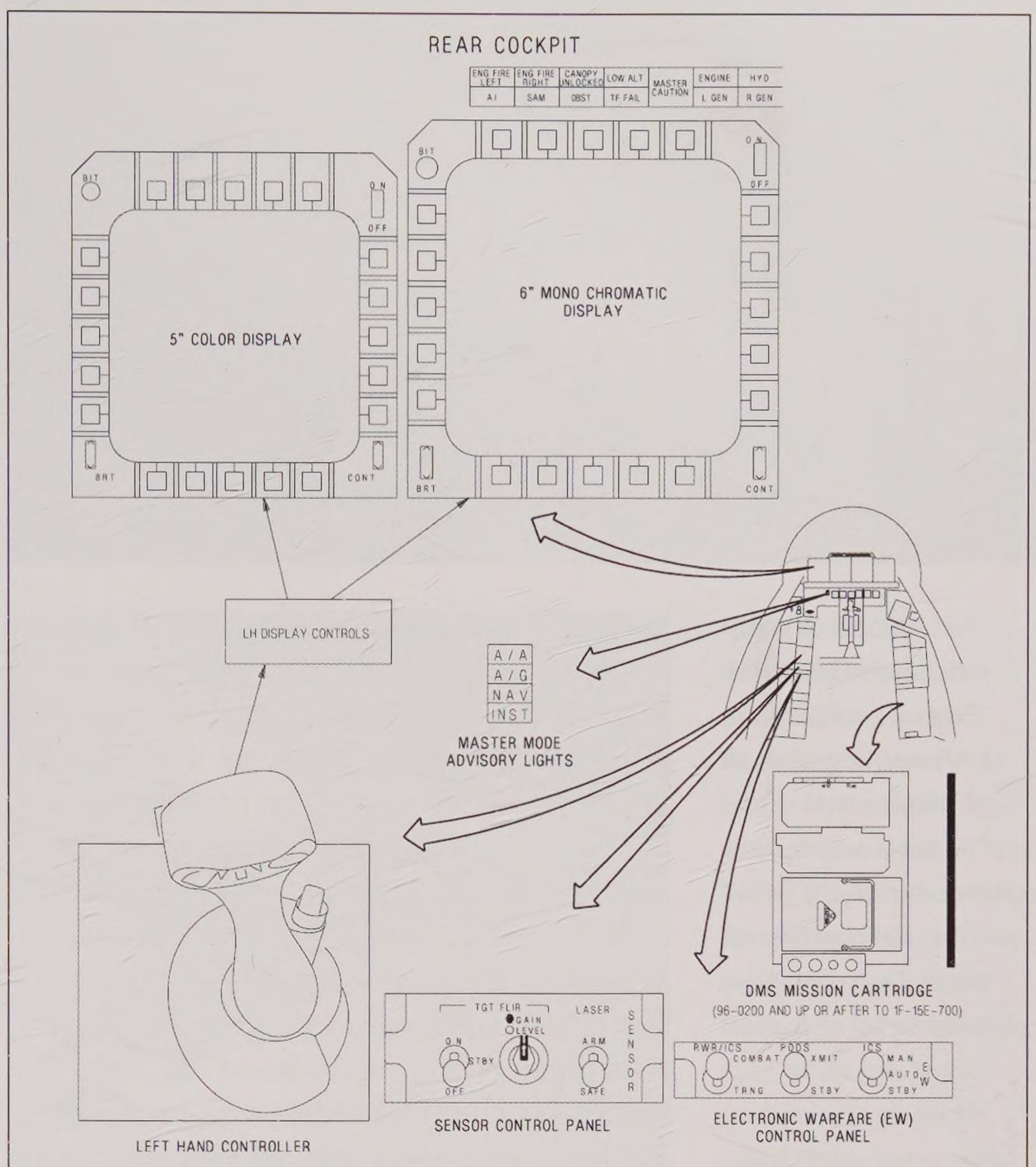
**LEFT The 1st Tactical Fighter Wing deployed to Prince Sultan AB, Saudi Arabia, on 7 August 1990, spearheading the entire coalition airpower force. This 71st TFS D-model sits outside one of PSAB's shelters, armed with four live AIM-9L Sidewinders and four AIM-7M Sparrows. The two-seat 'tub' jets were not used in combat, but were relied upon for local area familiarisation and continuation training sorties.** *(USAF)*

Operation Desert Shield began with the deployment of F-15Cs and F-15Es to the Persian Gulf region. The 1st FW at Langley AFB sent 24 F-15C and 3 F-15D aircraft to Dhahran AB, Saudi Arabia, on 7 August. The next day, 25 F-15C/Ds arrived from the 27th TFS. The Eagles immediately began flying combat air patrols to protect Saudi Arabia's sovereign air space. The Eagles were the first coalition tactical air assets to arrive in theatre.

On 9 August the 336th TFS's F-15Es arrived at Thumrait AB, Oman, via Dhahran, Saudi Arabia. At this time, of course, the Strike Eagle was still so new that it was cleared to release only the 2,000lb Mk 84 and 500lb Mk 82 LDGP (low-drag general purpose) bombs, making it what amounted to little more than a very sophisticated dumb bomb truck. Nonetheless, the Strike Eagles were the coalition's only real strike capability in theatre at this critical time – the only credible strike capability that could slow (but, it was accepted, not halt) an Iraqi ground assault into Saudi. As it turned out, the threat of further advances by Iraqi ground forces passed and the Rocketeers and 335th TFS Chiefs (who had by now joined the Rocketeers) moved to Al Kharj AB, Saudi Arabia, in December.

USAF Europe's growing commitment to the build-up continued, with the 53rd TFS, 36th TFW, sent 24 MSIP II F-15Cs from Bitburg Air Base, Germany, deploying to Prince Sultan AB, Saudi Arabia, on 20 December. Meanwhile, sister squadron the 525th TFS deployed to Incirlik AB, Turkey, to patrol Iraq's northern territories. Additional F-15Cs from the 32nd TFS, Soesterberg AB, the Netherlands, later joined the Turkish-based 525th TFS, arriving on the first day of the war – 17 January 1991.

In Riyadh, Saudi Arabia, coalition representatives and the US had formed the Tactical Air Control Centre (TACC) to plan the air war. The TACC published the 600-page Air Tasking Order (ATO) – the route map for the air




**ABOVE Where the F-15 had refined HOTAS, the F-15E introduced two hand controllers for the WSO, enabling him or her to access almost all of the jet's attack capabilities without ever having to remove their hands. The WSO also uses the controllers to scroll through 'pages' on their multi-purpose displays and multi-purpose colour displays.** *(USAF)*

**RIGHT Captain Rick 'Kluso' Tollini plays a Game Boy to unwind between sorties. Kluso planned the 33rd TFW's participation in the air war, and would claim a MiG-25 Foxbat in one of the Eagle's most exhilarating combat actions later in the war.** *(Rick Tollini via Steve Davies)*

**ABOVE A ramp full of F-15E Strike Eagles – initially the only coalition aircraft in theatre that could slow any further advance of Iraq's 'elite' Republican Guard.** *(Jerry Oney via Steve Davies)*

campaign against Iraq, which in its final iteration detailed every sortie that was to be flown for the first three days of the air war. Daily updates were then published for each day that followed.

The ATO tasked F-15Es primarily against SAM sites and key airfield complexes, but they were also assigned to the now infamous Scud-hunting mission. Iraq operated four types of tactical ballistic missiles, known to the coalition by the NATO designation 'Scud'. All four types were based on the original Soviet SS-1, a surface-launched missile with a range of over 200 miles. Iraq, it was believed, had adapted the Scud's warhead to carry chemical or biological loads, and showed no hesitation to use them against neighbouring countries. Naturally, it tasked the Eagle with protecting the strikers and rooting out and killing Iraq's Air Force.

On 17 January 1991 the order for the first strikes was given by President Bush – Operation Desert Storm (ODS) had begun. With the world's media filming what seemed like every minute, waves of coalition strikers took off to attack the 'eyes' and 'ears' of the Iraqi military machine. Iraq's IADS (integrated air defence system) was the primary target for many of the first sorties, with airfields, hardened aircraft shelters (HAS) and aircraft also being attacked so that air superiority could be attained. The ATO called for later strikes against Iraqi armour, C3 (command, control and communications) and logistics supplies, thus paving the way for a less protracted (and, hopefully, less bloody) ground war to rid Kuwait of its uninvited guests.

Five fixed Scud sites were hit by 24 F-15Es, that night. Divided into three-ship or four-ship packages, each F-15E carried two fuel tanks, 12 MK-20 Rockeye cluster bombs (which had been hastily cleared for release by the Strike Eagle), and two AIM-9M missiles. One flight attacked Scud sites at H-2 – an Iraqi air base – using 12 Mk 82s per jet.

For the air-to-air Eagles, the first night of the war provided the opportunity to draw first blood. 'Wall' formations – as many as eight Eagles in line abreast – fanned out in front of the strike packages as they entered Iraq. Acting almost like a fisherman's net, they corralled the Iraqi Air Force's fighters then killed them when they came within range of the AIM-7 Sparrow or AIM-9 Sidewinder missiles. The Eagles would claim six kills that first night, despite the fact that very stormy weather had caused havoc with their timings.

On Day 3, Eagles were escorting Strike Eagles on a Scud-hunting mission when kills seven

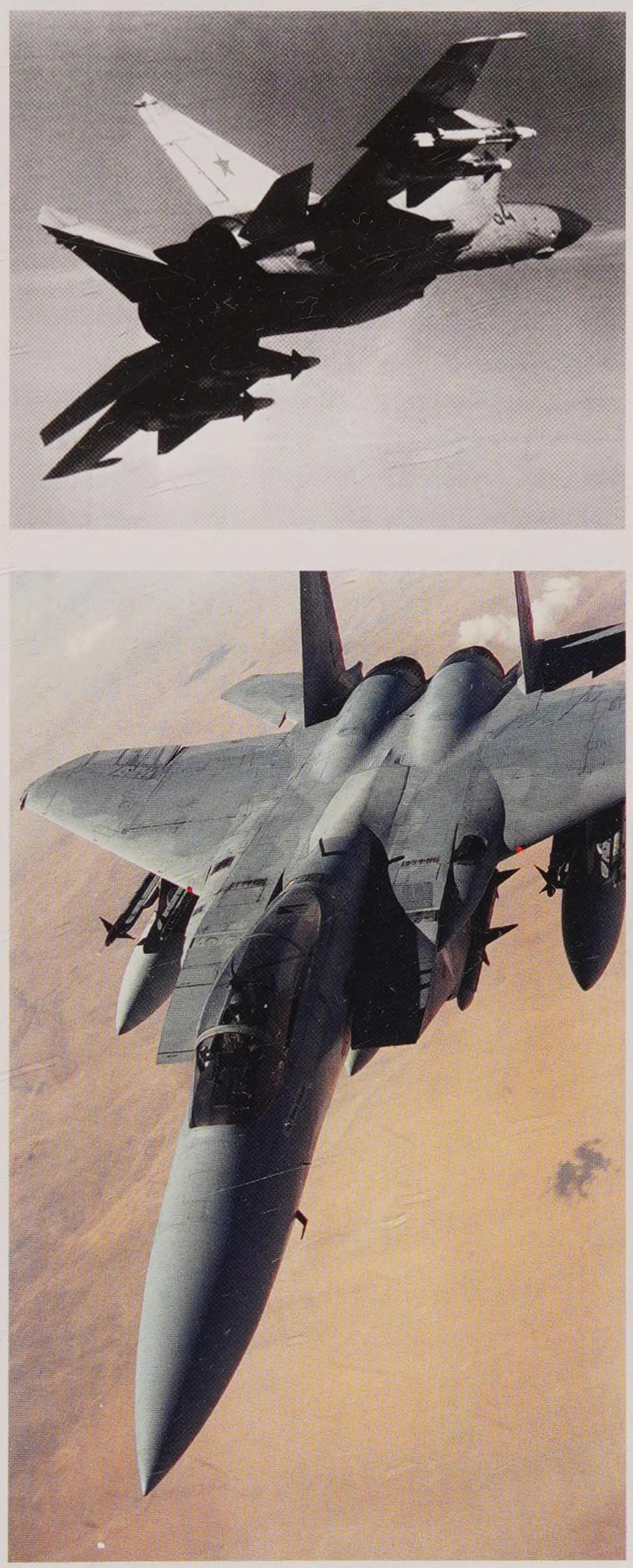
**LEFT The F-15E was so new that it was cleared to carry very few air-to-ground stores. One hastily approved configuration was this load of 12 Mk 20 Rockeye cluster munitions.** *(Jerry Oney via Steve Davies)*

**ABOVE** **The MiG-29 'Fulcrum' was the chief cause of concern to the Eagle pilots tasked with securing air superiority over Iraq. The 'Fulcrum' was smaller than the Eagle and extremely agile, and was similarly configured with twin vertical tails and twin engines, making visual identification problematic except at fairly close range.** *(USAF)*

and eight were claimed. Another four kills were claimed and awarded that day, bringing the total to 12. At that point the Iraqi Air Force effectively stood down – licking its wounds and not even attempting to participate in the fight. But, with Strike Eagles and other coalition fighters 'plinking' Iraq's hardened aircraft shelters – dropping laser-guided bombs on to them, and destroying the MiGs, Mirages and Sukhois that were supposed to be safely ensconced within – the Iraqi Air Force decided to flee. On Day 10 the Eagle's killing spree continued, and, in the 48-hour period that followed, eight more kills were achieved against Iraqi fighters attempting to flee to the relative safety of Iran or Syria.

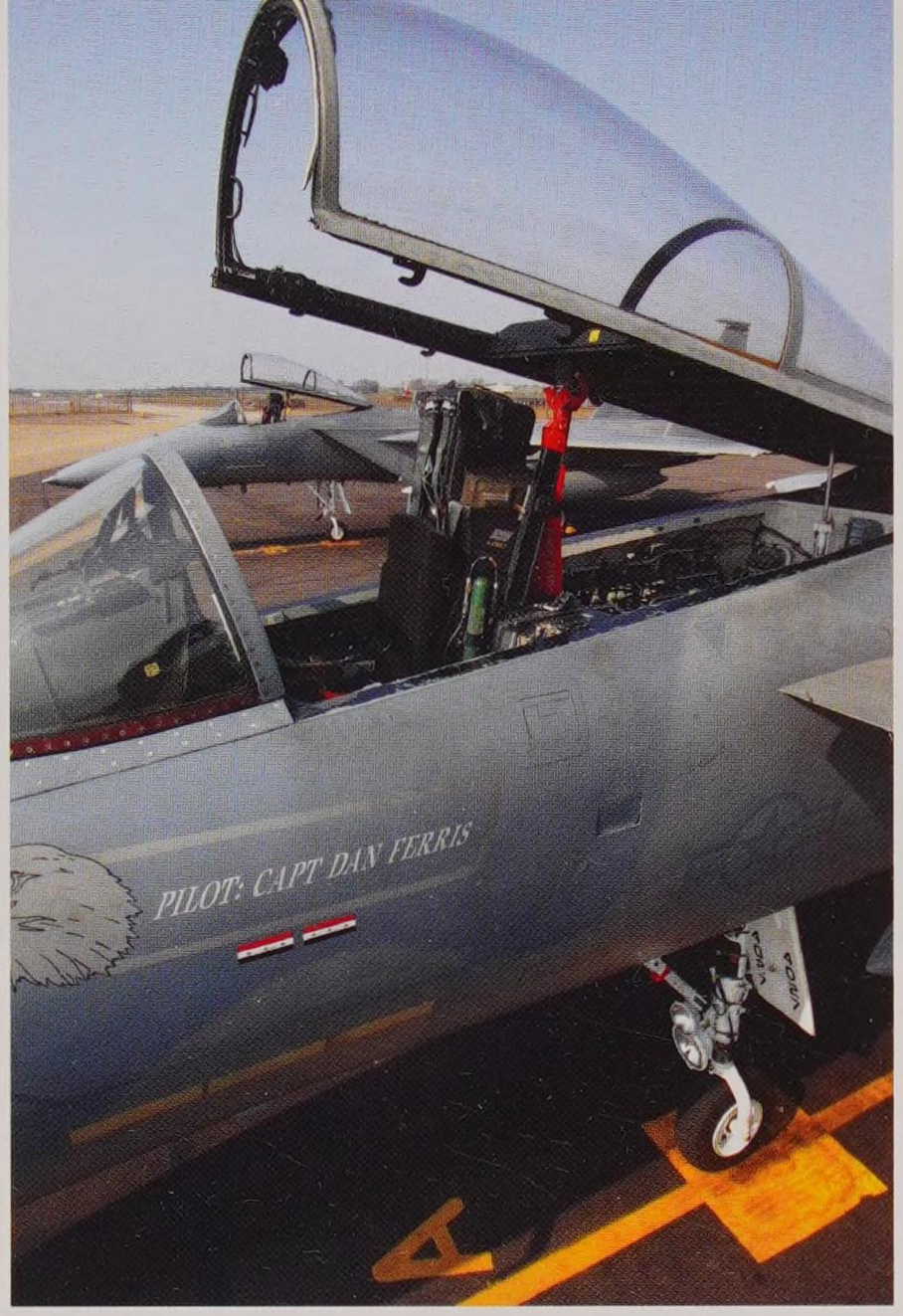
For the Strike Eagle, success was less easy to define. The new strike fighter had done well against fixed targets, and losses had been low (only two F-15Es were lost to enemy action during the war), yet the mobile Scud threat had not been adequately dealt with: Iraq had been able to launch Scuds against both Saudi Arabia and Israel with relative impunity.

The Scud-hunting challenge was significant for a number of reasons. Firstly, the Iraqi Scud operators were true masters of camouflage and deception, placing Scuds beneath culverts and (it later transpired) using civilian Winnebago



**LEFT** **From the rear it is easy to see how a MiG-25 could be mistaken for an F-14 in a fast, hard-turning engagement. When Rick Tollini (pictured on page 39 playing a Game Boy) shot down a 'Foxbat' he had to be absolutely sure of its identity – particularly since he knew there were Navy F-14s in the area. He called calmly: 'Everyone come out of burner *now*!' Only when the aircraft in front of him stayed in afterburner did he press the pickle button.** *(USAF)*

**LEFT** **F-15s in ODS nearly always carried three fuel tanks to war. At a predetermined range in an engagement the call to jettison would be made, and all three 'bags' would tumble away. Jettison airspeed limits were imposed to allow the fuel tanks to separate cleanly, but more than one Eagle pilot broke the limit in the heat of combat.** *(USAF)*




**RIGHT With two Iraqi flags painted below the canopy railing and the number '4027 on the nose-wheel door, this Eagle is identifiable as F-15C 84-0027, which was being flown by Captain Benjamin Powell when he killed a Mirage F.1EQ and a MiG-23 in a single engagement in Operation Desert Storm. It is today flown by the 493rd FS, 48th FW, RAF Lakenheath, England.** *(Steve Davies/ FJPhotography.com)*

**BELOW Loosing off an AIM-7 while in a banked turn, this F-15C is photographed over the Florida Gulf during a weapons trial. The AIM-7 was a very big missile – large enough that it was colloquially referred to as a 'freight train'.** *(USAF)*

camper vehicles to transport the missiles in plain sight. Secondly, the Strike Eagle's AAQ-14 target pod was in critically short supply (to the point that often only one aircraft in a formation of four would be equipped with it), and in any case, it lacked the resolution necessary to accurately identify a mobile Scud camp. As an example, on more than one occasion post-combat analysis showed that a 'mobile Scud launcher' struck by a laser-guided bomb had actually been a train of camels or a large herd of sheep.

On a more positive note, the Strike Eagle had joined the air-to-air kill club in mid-January, having successfully guided a GBU-10 2,000lb laser-guided bomb on to a hovering Iraqi helicopter.

Despite the fact that Operation Desert Storm was a short conflict (it lasted little more than a few months), the Eagle and Strike Eagle had performed exceptionally well. The F-15E flew 7,700 combat hours in around 2,400 sorties, while the F-15C claimed its 34th and final kill of the conflict on Day 65.

## The Balkans

From 1993 onwards, F-15s supported a range of NATO and UN operations in the Balkan theatre, providing more opportunities to 'shoot down what's up and blow up what's down'.

In June 1991 the former Yugoslavia began its violent break-up when the Republic of Slovenia and Croatia declared independence from the Federal Government in Belgrade. When civil war broke out in Bosnia a year later, the United Nations passed Resolution 757, introducing economic sanctions against Serbia and Montenegro.

NATO operations commenced in earnest when AWACS aircraft began monitoring a no-fly zone over Bosnia-Herzegovina in October 1992 under the auspices of UN Security Council Resolution 781. Operation Deny Flight commenced on 12 April 1993, and involved a range of UN reconnaissance and fighter aircraft, mostly operating from air bases in Italy, enforcing the no-fly zone. By July, F-15Cs from Bitburg's 53rd FS had flown over 660 combat air patrol (CAP) sorties protecting NATO troops on the ground in the Balkan regions of Banja Luca and Sarajevo.

The F-15E was also involved in this operation, with eight F-15Es from the 492nd FS 'Bolars', RAF Lakenheath, England, deployed to Aviano AB, Italy, on 12 April. Alongside them was a small delegation of Strike Eagles from sister squadron 494th FS 'Panthers'. The Strike Eagles executed ground strikes when relations between NATO and Serbia worsened. Udbina airfield was targeted by a NATO package of 30 aircraft, of which eight were 492nd Strike Eagles carrying 500lb GBU-12 laser-guided bombs. F-15Es were again in combat in December, this time striking a pair of SA-2 SAM sites.

In early 1994 USAF F-16s downed four

Serbian jets as they contravened the no-fly zone. Over the course of the year diplomatic efforts deteriorated, leading in November 1994 to a limited NATO strike against Serbian targets in Croatia, in particular Udbina airfield. The strike force of some 30 aircraft included F-15Es, and was protected by F-15Cs.

When Serbian forces shelled the market square in Sarajevo in August 1995, Operation Deliberate Force was activated in response. The 90th FS 'Dicemen' deployed its F-15Es from Elmendorf AFB, Alaska, for several months, joining the 492nd FS and 494th FS who already had eight jets each in theatre and had by this point flown well over 2,500 sorties since Operation Deny Flight.

Five punitive strikes hit Serbian armour and supplies around Sarajevo on 30 August. A day later, three more strikes were flown. On 5 September 2,000lb GBU-10s and 500lb GBU-12s were dropped by Lakenheath F-15Es as the strikes became more widespread. Four days later, the GBU-15 optically-guided glide bomb was used in anger by the F-15E for the first time. Nine of these 2,000lb weapons were employed against air defence targets around Banja Luca, the crews bringing back video footage of the bombs being flown directly into their targets. Once again, these strikes were protected by the F-15C.

Operation Deliberate Guard, another UN-mandated no-fly zone in the airspace over the Republic of Bosnia-Herzegovina, then followed. The 494th FS deployed once more to Aviano AB, Italy, on 30 September 1997, returning in January 1998.

Months later the best-known of the Balkan operations came into being. Operation Allied Force (OAF) began, following the displacement of some 300,000 refugees from Kosovo. Following repeated NATO warnings to Serbian President Milosevic to remove his armed forces from Kosovo, the first NATO forces arrived, including six 492nd FS F-15Es. An additional 12 F-15Es from the 492nd FS were sent to Italy on 22 January 1999 – all US assets operated under the code name Operation Noble Anvil.

Noble Anvil commenced on the night of 24 March 1999, when the F-15C claimed more kills. Following several cruise missile (CALCM) strikes by B-52s, 26 F-15Es struck air defence

targets, led by a wall of Lakenheath F-15Cs flying offensive counter air sorties (OCA). Two MiG-29s fell victim to AIM-120 AMRAAM missiles fired by two F-15Cs.

Then, on 26 March, the Eagle scored its first multi-bandit kill – two missiles simultaneously in the air against two separate targets – when a 493rd FS Eagle used his APG-70 and AMRAAM pairing to down two MiG-29s. The pilot engaged the two Fulcrums from inside 16 miles while in a 'Track While Scan' radar mode, launching a missile against the nearest threat, then immediately shooting against the second threat.

**ABOVE The GBU-12, a 500lb laser-guided bomb, has become a staple munition for the F-15E. Here, a crewman checks that the bombs are properly suspended from the CFT. He will also check for correct fusing, and that the weapon's seeker is programmed to look for the same laser code as the target pod will use.** *(USAF)*

**LEFT From front to back, an F-15C, MiG-29 and F-15E fly in formation. The MiG-29 is clearly smaller than the Eagle and Strike Eagle, but it is similar enough in size and shape that a fleeting glimpse in the heat of combat may not be enough for a pilot to make a concrete visual identification.** *(USAF)*

**ABOVE Lakenheath's Eagles were in the thick of it during much of the 1990s, operating in both the Middle East for ONW and OSW, and the Balkans for a range of NATO operations. Here the orange afterburner of the PW-220 makes for a spectacular take-off.** *(Steve Davies/ FJPhotography.com)*

As the conflict progressed, the F-15E employed the 5,000lb GBU-28A/B, a bunker-penetrating laser-guided bomb, for the first time. The target was an underground hangar at Pristina AB. When the threat was too high to penetrate, or specific weapons effects were required, the F-15E employed the AGM-130 optically guided stand-off bomb.

The F-15E was the only allied aircraft to operate in all weathers, day or night, and Allied Force was the first occasion on which night-vision goggles were used by the F-15E community in combat. One other significant change was the dual role of the F-15E during the conflict; the AIM-120 enabled the F-15E to change role from striker to air defence fighter once it had dropped its bombs.

Milosevic finally relented and allowed some of the thousands of displaced Kosovan Albanian refugees back to their homes. Operation Joint Guardian was subsequently activated to provide administrative oversight and security to this process. The 492nd FS redeployed on 10 January 2000, for three months, with six jets; so too did the 494th FS, from 22 May to 23 June the same year.

## Watchful Eagles and Strike Eagles

Since the cessation of Operation Desert Storm in mid-1991, the US and British armed forces had maintained a presence in the Gulf region, enforcing no-fly zones in Iraq's northern and southern parallels. These were known as Operation Northern Watch (ONW) and Operation Southern Watch (OSW) respectively.

**RIGHT A gaggle of Strike Eagles take gas from a KC-135 Stratotanker. Air refuelling extended the Strike Eagle's already impressive combat range. During Operations Northern and Southern Watch this capability gave the Strike Eagle the ability to loiter for hours on end.** *(Jerry Oney via Steve Davies)*

For ONW and OSW, the Eagles hunted down Iraqi MiGs that penetrated the no-fly zones, while Strike Eagles engaged ground forces that threatened the coalition patrols, and could also pursue Iraqi fighter jets (Iraq's military helicopters were exempt from the no-fly zone rules).

From 1998 onwards deployments to OSW and ONW came under the guise of the newly coined Air Expeditionary Forces (AEF). AEF was the road map that defined, 15 months ahead of time, which units would deploy to which locations. Prince Sultan Air Base, Saudi Arabia, most frequently hosted F-15C deployments to OSW, but F-15E deployments were made to either Al Jaber AB, Kuwait, or Sheikh Isa AB, Bahrain, because regional politics made the basing of 'strikers' on Saudi soil a sensitive subject.

Incirlik AB, Turkey, provided the temporary domicile of F-15 squadrons deploying to ONW, but Turkey would interfere with coalition operations out of Incirlik, often ceasing flight operations from the base when the Turkish Air Force was operating against the Kurds in Northern Iraq.

The Strike Eagle flew several types of OSW sortie, including 'container' sorties, which involved penetrating the no-fly zone as strikers or defensive counter air fighters; and alert sorties, where crews waited to be scrambled against a target in the no-fly zone. They therefore had numerous opportunities to fly, and crews typically went aloft at least four times per week.

Container sorties were usually executed by a four-ship flight of F-15Es tasked to patrol a geographically prescribed 'container'. If they spotted a violation of the no-fly zone then they reported it and awaited further instructions from the Combined Air Operations Center (CAOC), which decided whether to execute any, one or more of what were known as 'response options', or ROs. Crews usually took off with imagery of three or four RO target areas on board, although it was unusual for more than a single RO to be executed on any given sortie.

Alert sorties were, by definition, less proactive and more reactive: aircrew remain dressed in full flight gear (flight suit, g-suit, parachute harness and survival vest) for the duration of the 12-hour shift. This was notoriously uncomfortable, but it was essential if they were to be able to get strapped into the jets and ready to taxi within two to three minutes of receiving the call from the CAOC. Such calls typically arose when either an aircraft or ground contact required further investigation.

## Afghanistan and Operation Enduring Freedom

In the immediate aftermath of the 11 September 2001 terrorist attacks on the United States, President George W. Bush ordered his military forces into action. Their task was to remove the so-called Al-Qaeda terrorist group from Afghanistan, and to punish Afghanistan's rulers, the Taliban, who had sheltered them. Operational Enduring Freedom was under way.

While Light Grey Eagles of the Active Duty air force and the Air National Guard were protecting cities and potential targets in the continental United States from repeat attacks as part of Operation Noble Eagle, Strike Eagles headed east. Twelve F-15Es from the 391st FS, Bold Tigers, left Mountain Home AFB, Idaho, on 12 October 2001, and began a lengthy trip to Ahmed Al Jaber Air Base, Kuwait. Here they began operations under the command of the 332nd Air Expeditionary Group. The Strike Eagles belonged to Mountain Home's 366th Air Expeditionary Wing, a 'composite wing' made up of F-15s, F-16s, KC-135 tankers and B-1B bombers, whose *raison d'être* was to be ready

**BELOW 'Let's roll!' became the war cry of the US military in the wake of the 11 September terrorist attacks of 2001. This 391st FS F-15E sits on the ramp at Mountain Home AFB, Idaho, having just returned from Afghanistan.** *(Steve Davies/ FJPhotography.com)*

# F-15A/B/C/D KILLS

| | | | | | |
|---|---|---|---|---|---|
| **USAF** | | | | | |
| 17/1/91 | 85-0125 | Capt John Kelk | 58th TFS | AIM-7M | MiG-29 |
| 17/1/91 | 85-0105 | Capt Robert E. Graeter | 58th TFS | AIM-7M | 2 x Mirage F1EQs |
| 17/1/91 | 85-0119 | Capt Rhory Draeger (59th TFS) | 58th TFS | AIM-7M | MiG-29 |
| 17/1/91 | 85-0107 | Capt Charles Magill (USMC) | 58th TFS | AIM-7M | MiG-29 |
| 17/1/91 | 83-0017 | Capt Steve Tate | 71st TFS | AIM-7M | Mirage F1EQ |
| 19/1/91 | 85-0099 | Capt Larry Pitts | 58th TFS | AIM-7M | MiG-25 |
| 19/1/91 | 85-0101 | Capt Richard C. Tollini | 58th TFS | AIM-7M | MiG-25 |
| 19/1/91 | 85-0122 | Capt Craig Underhill | 58th TFS | AIM-7M | MiG-29 |
| 19/1/91 | 85-0114 | Capt Cesar A. Rodriguez Jr | 58th TFS | Ground | MiG-29 |
| 19/1/91 | 79-0021 | Lt David G. Sveden | 525th TFS | AIM-7M | Mirage F.1EQ |
| 19/1/91 | 79-0069 | Capt David S. Prather | 525th TFS | AIM-7M | Mirage F.1EQ |
| 26/1/91 | 85-0104 | Capt Anthony Schiavi | 58th TFS | AIM-7M | MiG-23 |
| 26/1/91 | 85-0108 | Capt Rhory Draeger (59th TFS) | 58th TFS | AIM-7M | MiG-23 |
| 26/1/91 | 85-0114 | Capt Cesar A. Rodriguez Jr | 58th TFS | AIM-7M | MiG-23 |
| 27/1/91 | 84-0025 | Capt J.T. Denney | 53rd TFS | AIM-9M | 2 x MiG-23s |
| 27/1/91 | 84-0027 | Capt Benjamin D. Powell | 53rd TFS | AIM-7M | MiG-23 & Mirage F.1EQ |
| 28/1/91 | 79-0022 | Capt Donald S. Watrous | 32nd TFS | AIM-7M | MiG-23 |
| 29/1/91 | 85-0102 | Capt David Rose (60th TFS) | 58th TFS | AIM-7M | MiG-23 |
| 2/2/91 | 79-0064 | Capt Gregory Masters | 525th TFS | AIM-7M | IL-76 |
| 6/2/91 | 79-0078 | Capt Thomas N. Dietz | 53rd TFS | AIM-9M | 2 x MiG-21s |
| 6/2/91 | 84-0019 | Lt Robert Hehemann | 53rd TFS | AIM-9M | 2 x Su-25s |
| 7/2/91 | 85-0102 | Capt Anthony R. Murphy | 58th TFS | AIM-7M | 2 x Su-22s |
| 7/2/91 | 84-0124 | Col Rick Parsons | 58th TFS | AIM-7M | Su-7 |
| 7/2/91 | 80-0003 | Maj Randy May | 525th TFS | AIM-7M | Mi-24 |
| 11/2/91 | 79-0048 | Capt Mark Mckenzie | 525th TFS | AIM-7M | 0.5 Mi-8 |
| 11/2/91 | 80-0012 | Capt Steven Dingee | 525th TFS | AIM-7M | 0.5 Mi-8 |
| 20/3/91 | 84-0014 | Capt John Doneski | 53rd TFS | AIM-7M | Su-22 |
| 22/3/91 | 84-0010 | Capt Thomas N. Dietz | 53rd TFS | AIM-9M | Su-22 |
| 22/3/91 | 84-0015 | Lt Robert W Hehemann | 53rd TFS | Ground | PC-9 |
| 24/3/99 | 86-0169 | Lt Col Cesar A. Rodriguez Jr | 493rd FS | AIM-120 | MiG-29 |
| 24/3/99 | 86-0159 | Capt Mike Shower | 493rd FS | AIM-120 | MiG-29 |
| 26/3/99 | 86-0156 | Capt Jeff Hwang | 493rd FS | AIM-120 | 2 x MiG-29s |
| **Royal Saudi Air Force** | | | | | |
| 5/6/84 | Unknown | Unknown | | AIM-7 | IRAF F-4E |
| 24/1/91 | 80-0068 | Saleh Al-Shamrani | 13 Sqn | AIM-9M | 2 x IRAF Mirage F.1EQs |
| **Israeli Air Force** | | | | | |
| 27/6/79 | 663 | Moshe Melnik | F-15A | | MiG-21 |
| 27/6/79 | 689 | Eitan Ben-Eliyahu | F-15A | | MiG-21 |
| 27/6/79 | 704 | Joel Feldschuh | F-15B | | MiG-21 |
| 27/6/79 | 672 | Yoram Peled | F-15A | | MiG-21 |
| 27/6/79 | ??? | Gay Golan (shared claim with Kfir C2) | F-15A | | 0.5 MiG-21 |
| 24/6/79 | 695 | Avner Nave | F-15A | | MiG-21 |
| 24/9/79 | 695 | Avner Nave | F-15A | | MiG-21 |
| 24/9/79 | 676 | Dedi Rozental | F-15A | | MiG-21 |
| 24/9/79 | 692 | Israel (Relik) Shafir | F-15A | | MiG-21 |
| 24/8/80 | 696 | Ilan Margalit | F-15A | | MiG-21 |

| | | | | | |
|---|---|---|---|---|---|
| 31/12/80 | 695 | Yoav Stern | F-15A | | MiG-21 |
| 31/12/80 | 646 | Yair Rachmilevitz | F-15A | | MiG-21 |
| 31/12/80 | Unknown | Yoram Peled | F-15A | | MiG-21 |
| 3/2/81 | 672 | Benyamin Zinker | F-15A | | MiG-25 |
| 29/7/81 | 673 | Sha'ul Simon | F-15A | | MiG-25 |
| 10/2/82 | Unknown | Miki Lev | F-15? | | MiG-21 (unconfirmed kill) |
| 7/6/82 | 658 | Offer Lapidot | F-15A | | MiG-23 |
| 8/6/82 | 686 | Yoram Hofman | F-15A | | MiG-21 |
| 8/6/82 | Unknown | Moshe Melnik | F-15 | | MiG-21 |
| 8/6/82 | 957 | Sha'ul Schwartz/Reuven Solan | F-15D | | MiG-21 |
| 8/6/82 | 818 | Sha'ul Simon | F-15C | | 0.5 MiG-23 |
| 8/6/82 | 832 | Dedi Rozental | F-15C | | 0.5 MiG-23 |
| 9/6/82 | 684 | Yoram Peled | F-15A | | MiG-21 |
| 9/6/82 | 684 | Yoram Peled | F-15A | | MiG-21 (unconfirmed kill) |
| 9/6/82 | 658 | Gil Rapaport | F-15A | | MiG-23 |
| 9/6/82 | 646 | Avi Maor | F-15C | | MiG-23 |
| 9/6/82 | 646 | Avi Maor | F-15C | | MiG-21 |
| 9/6/82 | 684 | Ronen Shapira | F-15A | | MiG-23 |
| 9/6/82 | 686 | Ronen Shapira | F-15A | | MiG-21 |
| 9/6/82 | 802 | Moshe Melnik | F-15C | | MiG-21 |
| 9/6/82 | 802 | Moshe Melnik | F-15C | | MiG-23 |
| 9/6/82 | 695 | Oren Hampel | F-15A | | MiG-21 |
| 9/6/82 | Unknown | Unknown | F-15 | | MiG-21 (manoeuvre kill) |
| 9/6/82 | Unknown | Unknown | F-15 | | MiG-21 (manoeuvre kill) |
| 10/6/82 | 979 | Yoram Peled/Zvi Lipshitz | F-15D | | MiG-21 |
| 10/6/82 | Unknown | Joel Feldschuh | F-15 | | MiG-21 (unconfirmed kill) |
| 10/6/82 | 957 | Avner Nave/Michael Cohen | F-15D | | MiG-23 |
| 10/6/82 | 957 | Avner Nave/Michael Cohen | F-15D | | MiG-23 |
| 10/6/82 | 957 | Avner Nave/Michael Cohen | F-15D | | MiG-21 |
| 10/6/82 | 840 | Benyamin Zinker | F-15C | | MiG-23 |
| 10/6/82 | 848 | Zvi Nadivi | F-15C | | SA.342L |
| 10/6/82 | 828 | Gil Rapaport | F-15C | | MiG-23 |
| 10/6/82 | 802 | No'am Canaani | F-15C | | MiG-23 |
| 10/6/82 | 802 | No'am Canaani | F-15C | | MiG-23 |
| 10/6/82 | 708 | Sha'ul Schwartz/Uzi S. | F-15B | | MiG-21 |
| 10/6/82 | 848 | Yoram Hofman | F-15C | | MiG-21 |
| 10/6/82 | 955 | Miki Lev | F-15D | | MiG-21 |
| 10/6/82 | 667 | Yftach Shadmi | F-15A | | MiG-21 |
| 11/6/82 | 678 | Yoram Peled | F-15A | | MiG-23 |
| 11/6/82 | 678 | Yoram Peled | F-15A | | MiG-23 |
| 11/6/82 | 678 | Yoram Peled | F-15A | | MiG-23 |
| 11/6/82 | 646 | Offer Lapidot | F-15A | | MiG-21 |
| 11/6/82 | 840 | Yftach Shadmi | F-15C | | MiG-21 |
| 11/6/82 | 704 | Sha'ul Simon/Amir Chodorov | F-15B | | MiG-21 |
| 24/6/82 | 979 | Joel Feldschuh/Zvi Liphshitz | F-15D | | MiG-23 |
| 24/6/82 | 979 | Joel Feldschuh/Zvi Liphshitz | F-15D | | MiG-23 |
| 31/8/82 | 821 | Sha'ul Schwarz (shared with AAA) | F-15C | | 0.5 MiG-25 |
| 20/11/85 | 840 | Avner Nave | F-15C | | MiG-23 |
| 20/11/85 | 840 | Avner Nave | F-15C | | 0.5 MiG-23 |
| 20/11/85 | 957 | Yuval Ben-Zur/Ofer Patz | F-15D | | 0.5 MiG-23 |

at a moment's notice to deploy anywhere in the world. Highly flexible, therefore, the Bold Tigers operated not only within the USAF's pre-planned AEF assignments, but also as a 'crisis reaction Wing' to cover unplanned requirements.

Combat missions over Afghanistan began in mid-October. By the end of the month, Strike Eagles were employing AGM-130 and EGBU-15s – GPS-equipped versions of the optically guided GBU-15 – against caves leading to underground facilities. The GBU-24, a 2,000lb laser-guided bomb with low-altitude capabilities and fitted with the BLU-109 penetrator warhead, and the GBU-28 Bunker Buster bomb, were also both used for the destruction of reinforced targets and underground Taliban facilities. The GBU-28 in particular was employed against Taliban command and control centres and cave entrances; a total of five were dropped.

Within a matter of weeks, mission planners were discovering that they had almost exhausted their list of meaningful fixed targets in Afghanistan – repair of the country's military infrastructure had never been a priority for the Taliban. At this point the Strike Eagles began flying more Time Sensitive Tasking (TST) missions, TST targets being those that could move or hide if they were not attacked within a certain window of opportunity – *ie* people, vehicles etc.

When Troops in Contact (TIC) close air support became necessary, the F-15Es would venture down low to ensure maximum weapons and target identification accuracy. Several times they struck Taliban fighters who were so close to friendly troops that the forward air controllers (FAC) could only whisper their radio calls. The Bold Tigers also flew reconnaissance missions using the AAQ-14.

In January 2002 the Bold Tigers returned to Idaho, having achieved a sortie generation rate better than 85%, flying two to eight sorties every day. They were replaced by F-15Es of the 335th FS, 4th Wing, Seymour Johnson AFB.

Operation Enduring Freedom, and the Strike Eagle's contribution to that mission, would continue for more than a decade. This included operations for OEF – Horn of Africa (HOA), flying out of Djibouti-Ambouli International Airport. From here, detachments of F-15Es have supported ongoing operations against terrorist factions in the Arabian Peninsula, to include airstrikes against targets in Somalia and Yemen.

**BELOW The AGM-130 is a 2,000lb glide bomb powered by an underslung rocket pod. It was used by the F-15E for the first time during OSW, and since then has provided the Strike Eagle community with a reasonably reliable stand-off strike capability that has been of great use in the Balkans, Afghanistan and, once again, Iraq.** *(USAF)*

## The Second Gulf War – Operation Iraqi Freedom

As the United States and Great Britain pushed for regime change in Iraq in 2002, it became obvious that war with Saddam Hussein was once again imminent. Two Seymour Johnson F-15E squadrons – the 335th FS Chiefs and 336th FS Rocketeers – deployed 48 jets to Al Udeid AB, Qatar, accordingly. Later, in February and March 2003, F-15C Eagles of the 71st FS and 94th FS, 1st FW, Langley AFB, and the 58th FS, 33rd FW, Eglin AFB, were deployed to counter Iraq's air threat. The Gorillas, as the 58th FS is known, deployed on 6 March 2003 to King Faisal Air Base, Saudi Arabia. The 94th FS deployed to Incirlik AB, Turkey.

The Strike Eagles initially flew missions as part of OSW. It was later on during these sorties that they began flying NTISR – non-traditional intelligence surveillance and reconnaissance. Operation Iraqi Freedom (OIF) was drawing closer.

NTISR involved using the aircraft's onboard sensors – LANTIRN and LITENING pods, radar and ZSW-1 Data Link pod – to scour Iraq for targets of interest. NTISR sorties were flown under the 'Strike Familiarisation' banner, meaning that aircrew flew missions with live ordnance and with response options ready. But

these sorties were principally designed to allow aircrew to familiarise themselves with rules of engagement (ROE), local area procedures and flying over hostile territory, prior to all-out war.

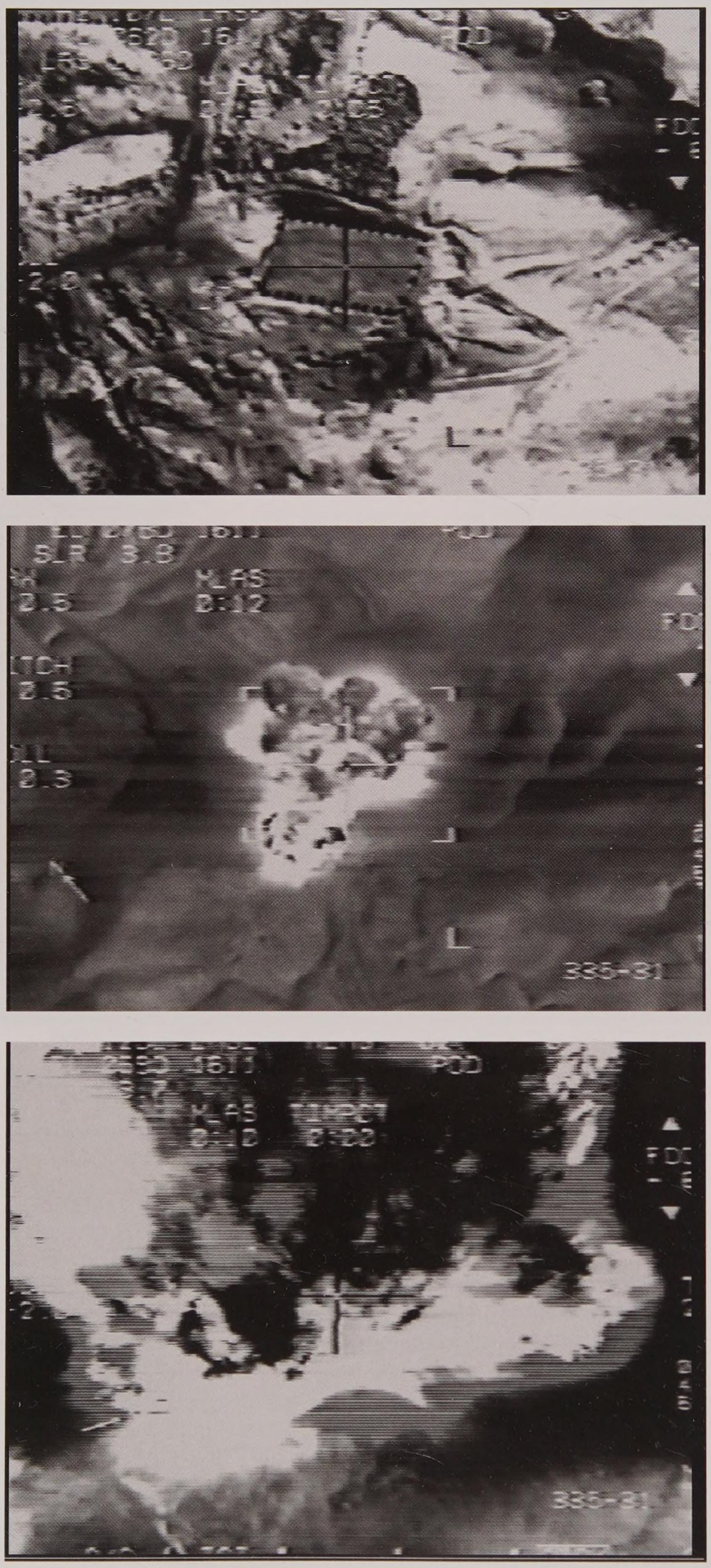
When war did come, it came earlier than had originally been planned by the CAOC. Operation Iraqi Freedom (OIF) began when four F-15Es flew a GBU-28 strike on the intercept operations centre of 'H-3', an Iraqi airfield, on 19 March. In the minutes that followed immediately after, two F-117s headed north at short notice to strike a target believed to house Saddam Hussein.

As the F-15Es returned from the strike against H3, still unaware that they'd just started the Second Gulf War, their radios came alive and blocks of airspace were cleared by AWACS to allow passage for incoming Tomahawk land attack cruise missiles. 'Shock and awe' was on its way.

The first full day of the war saw experienced Strike Eagle crews from both squadrons launch AGM-130 strikes against key leadership targets. The Chiefs struck Republican Guard barracks in the vicinity of Baghdad International Airport, while the Rockets struck Saddam Hussein's Yacht club – both target sets formed part of the Iraqi dictator's personal transportation infrastructure and were chosen to make it harder for him to flee the city in the coming hours. Of course, if he were at those sites and in the process of fleeing when the strikes went in, then so much the better.

The Strike Eagles also flew offensive counter

**ABOVE With flares spewing from the counter-munitions dispensers on the underside of the fuselage, a Strike Eagle shows off for the camera. The aircraft carries one of several mixed loads that became popular in Afghanistan and Iraq – in this case four GBU-12s on the CFTs and a GBU-31 joint direct attack munition (JDAM) on the centreline station.** *(USAF)*



**LEFT A three-photo sequence showing the acquisition and destruction of an Iraqi ammunition dump, as seen by an F-15E WSO. The FLIR picture from the target pod uses either black (black hot) or white (white hot) to denote heat, as desired by the crew. As the weapon impacts the target, an initial explosion is seen. Seconds later, a secondary explosion completely washes out the FLIR picture.** *(USAF)*

air missions that day. These air-to-air optimised aircraft were to push forward to quash any resistance from the Iraqi Air Force, and, whilst none was found, at least one pair of Strike Eagles moved its orbit further south as withering AAA and unguided SAM launches lit up the sky. One pilot reportedly counted as many as 40 SAM launches in the first hour of the war.

With the AGM-130 and OCA F-15Es airborne, the remaining Strike Eagles flew into Iraq to fly Kill Box Interdiction and pre-planned precision strike sorties across the length and breadth of the country – throughout the conflict, the Strike Eagle was the only airframe with the range, self-protection and target detection capabilities to roam freely in both northern and southern Iraq.

For the 'light grey' Eagles, there was little trade: the Iraqi Air Force rarely flew before OIF, and stopped flying altogether when coalition combat operations began in earnest. Business for the Eagles was so bad that all three squadrons would return home by May – they were simply consuming precious gas burning holes in the sky, it was said. The 58th FS departed for Eglin AFB, Florida, on 25 April having flown 2,046.5 combat hours and achieved an 83% Mission Capable rate. The 71st FS returned home having been deployed for a little over two months.

As for the F-15E, the 336th FS recorded a total time of 5,937.9 hours flown; 4,788.7 of those were combat sortie hours flown during the course of 1,768 individual combat sorties. The F-15E itself finished the war with a Mission Capable rate of 84.1%, higher than any other USAF fighter bar the far less active F-117 Nighthawk.

Iraqi Freedom would eventually prove to be a little like shooting ducks in a barrel. One Strike Eagle was lost, the cause never definitively established, while supporting special operations

**RIGHT High over Iraq, an F-15E provides cover to operators on the ground. It was while in this same configuration that an F-15E was lost over Libya during OOD – asymmetry caused by trapped fuel and an imbalanced weapons load caused the aircraft to depart controlled flight with little warning when the pilot pulled the aircraft into a turn. The crew ejected safely and were rescued quickly.** *(USAF)*

forces on the ground near Tikrit. Combat operations over Iraq (and, in particular, the lead up to OIF) were not without their challenges for the Strike Eagles, but the two squadrons performed well overall and the supremacy of the Strike Eagle in Iraqi airspace had never been in doubt.

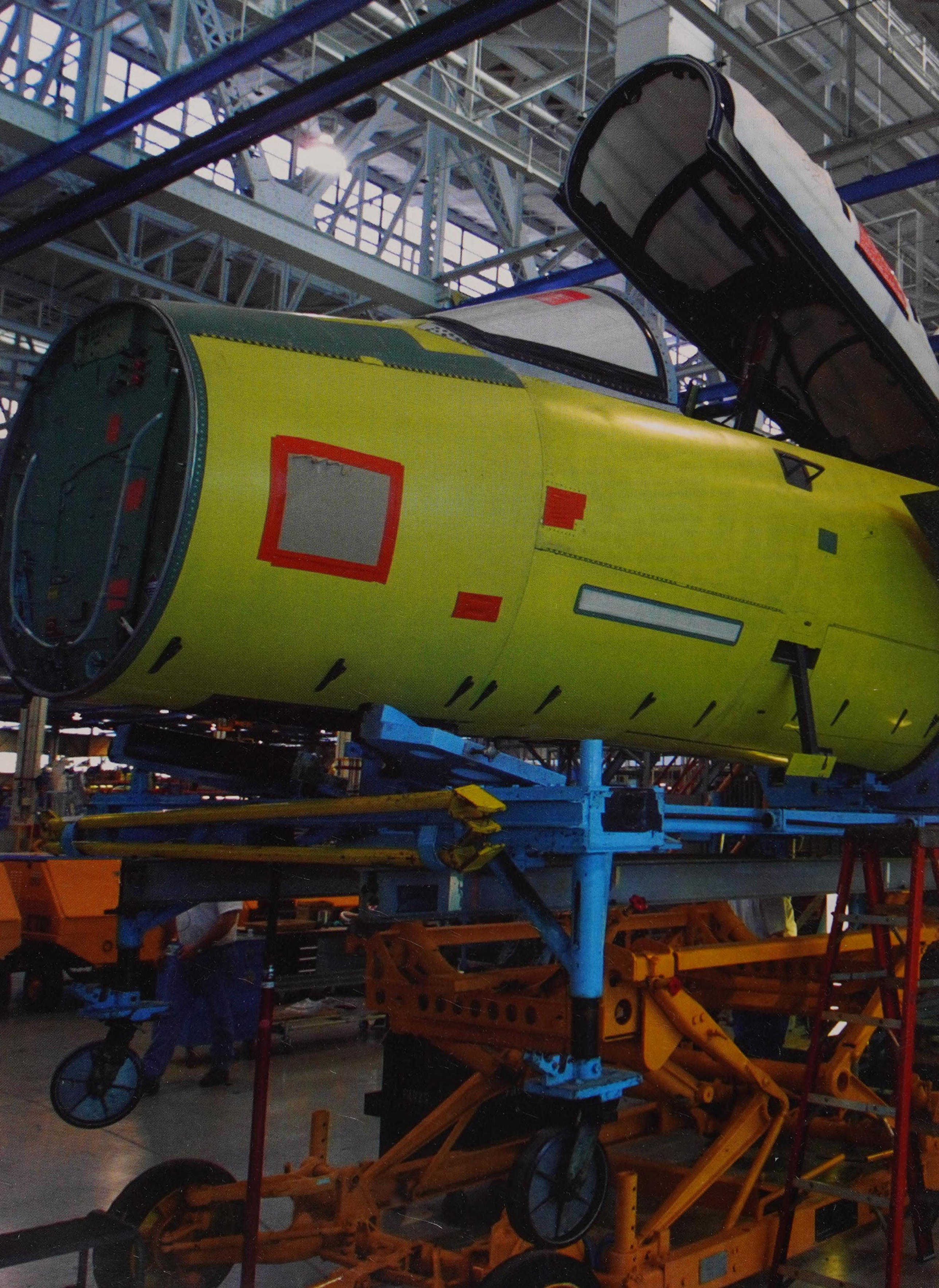
## Libya and Operation Odyssey Dawn

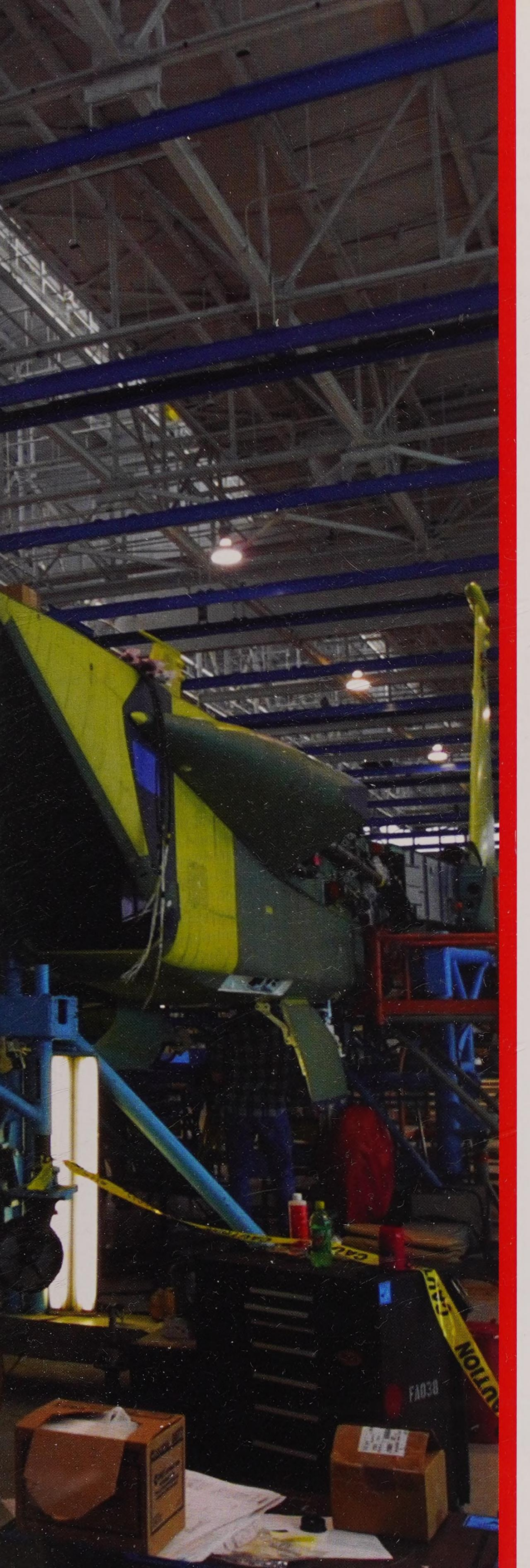
Most recently, the F-15E has seen action over Libya for Operation Odyssey Dawn (OOD). The operation to free Libya from the clutches of its dictator, Muammar Gaddafi, began on 19 March 2011, exactly eight years after the beginning of the Second Gulf War.

The United States deliberately took a less driving role in this conflict, leaving the coalition's eight other nation states to lead the action, yet still contributed a strong strike force that included F-15Es from Lakenheath's 494th and 492nd FSs. These aircraft deployed to Aviano AB, Italy, from where they initially struck air defence targets before taking time sensitive tasking missions.

Air operations continued for 161 days, ending soon after the capture of Gaddafi on 20 October. One Strike Eagle was lost when it departed controlled flight at high altitude during a combat mission on 21 March, but both crew ejected and were soon rescued.

**RIGHT The GBU-12, seen here on a 335th FS 'Chiefs' Strike Eagle, is the weapon of choice when engaging targets in urban settings. Reliable and with a relatively small lethal fragmentation pattern, it can be used to strike a single building (or part of a larger building) with a reduced risk of collateral damage.** *(Randall Haskin via Steve Davies)*





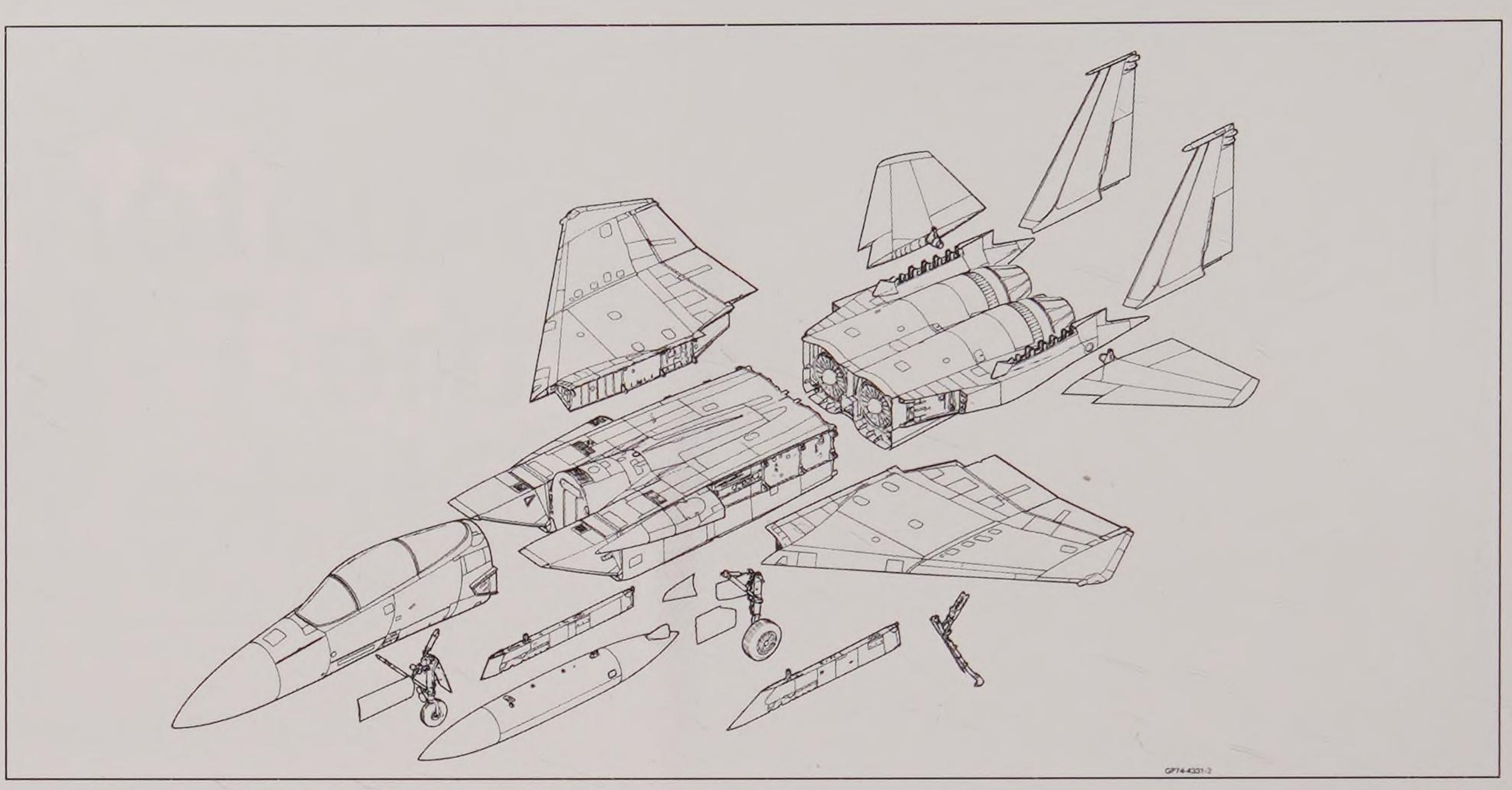
*Chapter Three*

# Anatomy of the F-15E Strike Eagle

**The following technical description of the F-15E is taken directly from the US Air Force's technical order manual for the Strike Eagle. Small edits have been made to simplify and improve the readability of the text, but it otherwise follows the original very closely.**

**OPPOSITE To protect the toughened Perspex, the canopy is covered with a heavy-duty stickyback layer.** *(Steve Davies/ FJPhotography.com)*

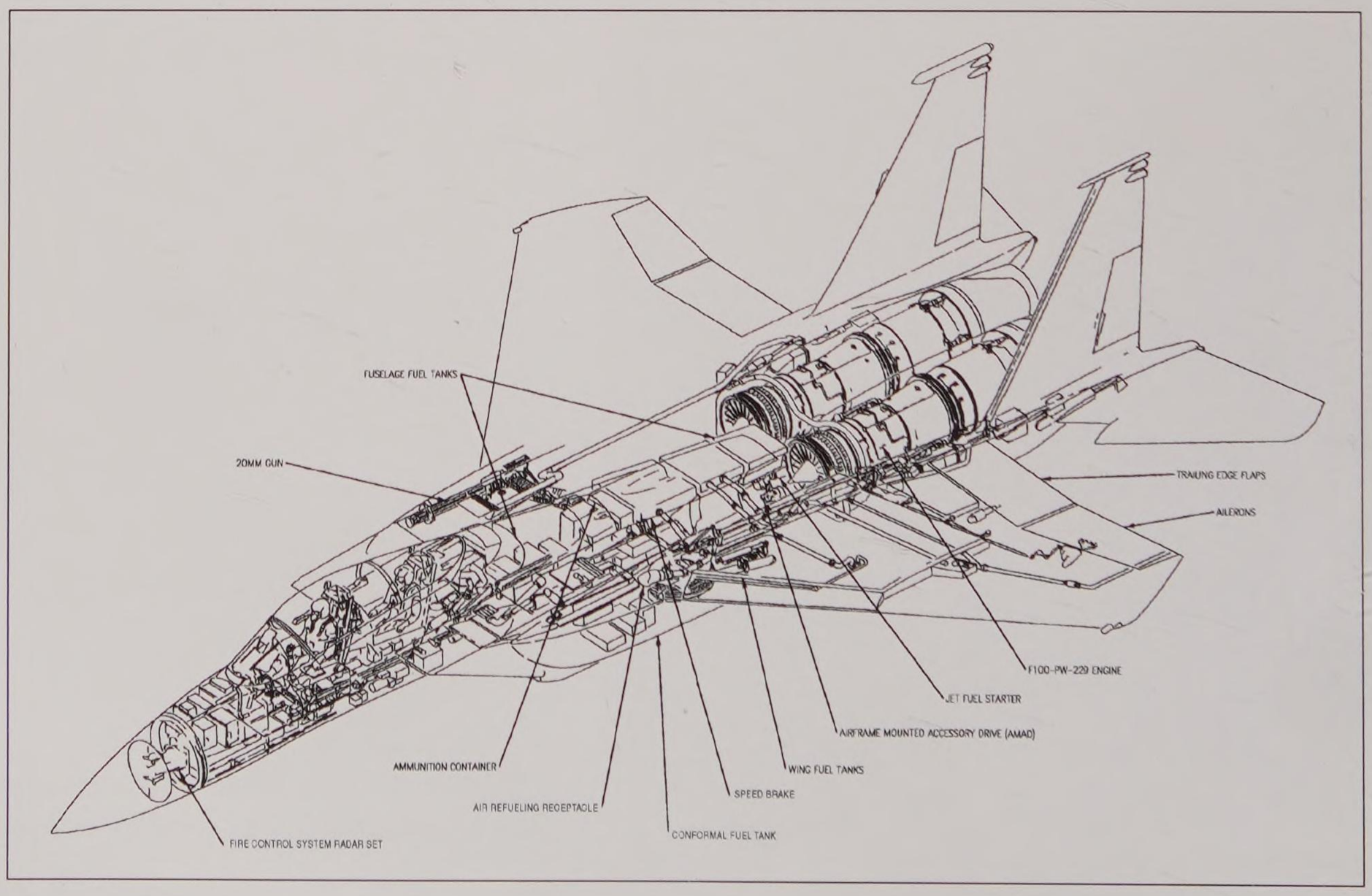
**RIGHT The major assemblies of the F-15, as shown in an original McAir schematic.** *(Boeing)*



# Introduction

The F-15E is a high-performance, supersonic, all-weather, dual-role fighter built by the Boeing Company. In the air superiority role, its primary weapons are radar-guided and infrared homing air-to-air (A/A) missiles and a 20mm gun. In the interdiction role, the aircraft carries low altitude navigation targeting infrared for night (LANTIRN) targeting and navigation pods on dedicated sensor stations under the left and right engine inlets and can carry a variety of guided and unguided air-to-ground (A/G) weapons.

The aircraft is powered by two Pratt & Whitney F-100-PW-229 turbofan engines. Aircraft appearance is characterised by a high-mounted swept-back wing and twin vertical stabilisers. The cockpits are elevated to enhance visibility. The basic aircraft configuration is with conformal fuel tanks (CFTs) and without pods or pylons. CFTs with tangential carriage of A/A weapons can be removed. A jet fuel starter (JFS) provides self-starting of the engines. Aircraft systems are designed and located for high maintainability and reliability.




**RIGHT The general arrangement of the F-15E differs little from that of the F-15D or F-15B. Whilst externally very similar, the F-15E is internally 'beefed up' – the result of improved titanium manufacturing techniques.** *(USAF)*

## Dimensions

The approximate overall dimensions of the aircraft are:

Span – 42ft 10in.

Length – 63ft 9in.

Height to top of vertical tail – 18ft 8in.

Height to top of closed canopy – 12ft.

Distance between main landing gear – 9ft.

## Weights

(The following weights in pounds are approximate.)

Operating weight (basic weight plus crew) – 37,500lb; without CFTs 33,500lb.

Take-off gross weight (operating weight plus full internal fuel, full centreline fuel tank, ammunition, LANTIRN pods, wing pylons and four LAU-128 missile racks) – 68,000lb (54,500lb).

Take-off gross weight as above plus two full external wing fuel tanks – 76,500lb (63,500lb).

Maximum gross weight – 81,000lb.

## TECH SPECS – F-15A/B/C/D

### Dimensions and weights

| | | |
|---|---|---|
| Length | | 63ft 9in (19.43m) |
| Height | | 18ft 8in (5.69m) |
| Wingspan | | 42ft 10in (13.06m) |
| Basic take-off weight (operating weight) | | F-15A – 39,400lb (27,700lb)<br>F-15B – 39,800lb (28,100lb)<br>F-15C – 42,100lb (28,600lb)<br>F-15D – 42,600lb (29,100lb) |

### Motors

Two Pratt & Whitney F100-PW-100, PW-220 or PW-220E turbofan engines with afterburners.

| | | |
|---|---|---|
| Thrust | PW-100 | 23,900lb (10,855kg) |
| | PW-220 | 23,450lb (10,637kg) |
| | PW-220E | 23,900lb (10,855kg) or 29,000lb (13,154kg) |

### Performance

| | |
|---|---|
| Speed | 1,875mph (Mach 2.5+ at sea level) |
| Ceiling | 65,000ft (19,697m) |

### Range

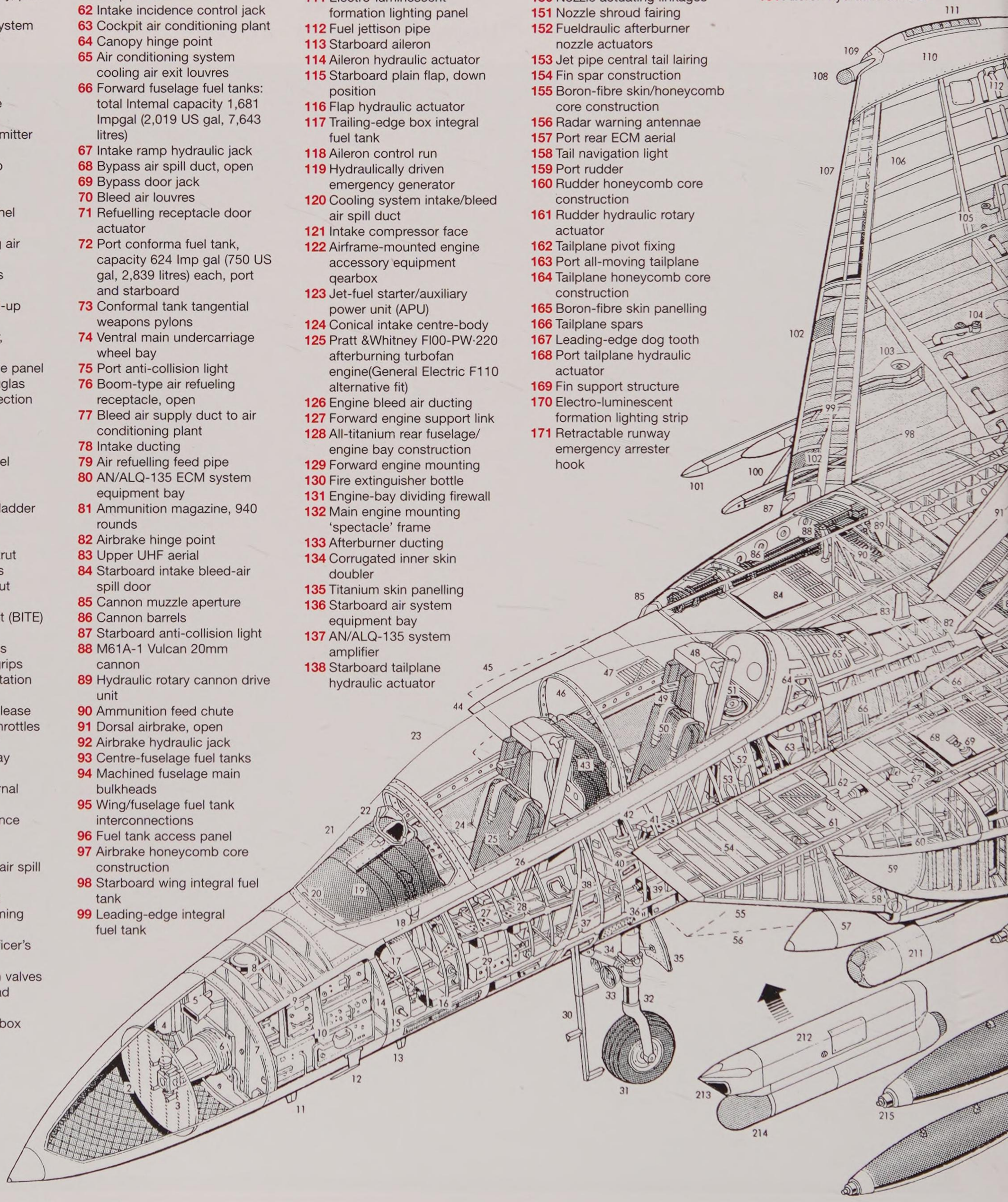
| | |
|---|---|
| Ferry range +3 external tanks | 2,878 miles (4,631km) |
| Ferry range +3 external tanks and CFT | 3,450 miles (5,552 km) |

**BELOW The Eagle's maximum speed is listed as Mach 2.5+, but in truth few operational Eagles are in good enough condition to achieve that speed. As this portrait of a 483rd FS Eagle shows, the Eagle is an undeniably beautiful fighter.** *(Steve Davies/FJPhotography.com)*

## McDonnell Douglas/Boeing F-15E Strike Eagle

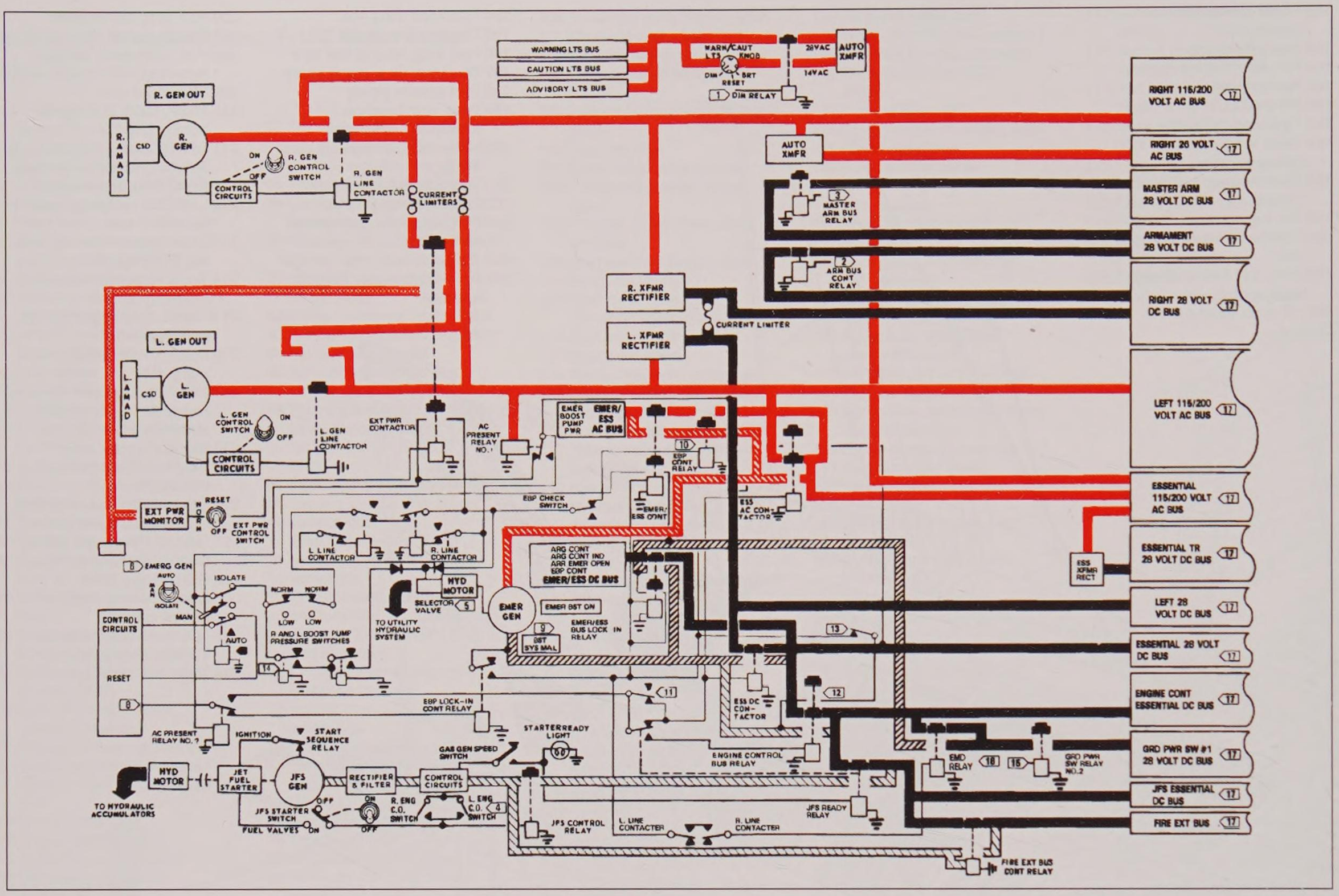
*(Mike Badrocke)*

1 Glassfibre radome
2 Hughes APG-70 pulse-Doppler radar scanner
3 Scanner tracking mechanism
4 Radome hinge
5 Wide band radar Flood Horn
6 Scanner mounting
7 Radome bulkhead
8 ADF sense aerial
9 Avionics equipment bay, port and starboard
10 APG·70 multi-mode system equipment
11 UHF aerial
12 Pitot head
13 TACAN aerial
14 Cockpit front pressure bulkhead
15 Angle of attack "transmitter
16 Electro-luminescent formation lighting strip
17 Rudder pedals
18 Control column
19 Instrument/display panel shroud
20 Windscreen demisting air duct
21 Single piece frameless windscreen panel
22 Pilot's wide-field head-up display (HUD)
23 Cockpit canopy cover, upward hingeing
24 Starboard side console panel
25 Pilot's McDonnell Douglas ACES II 'zero-zero' ejection seat
26 Cockpit coaming
27 Engine throttle levers
28 Port side console panel
29 Underftoor avionics equipment bay
30 Retractable boarding ladder
31 Nosewheel, forward retracting
32 Shock absorber leg strut
33 Landing/taxying lamps
34 Retraction/breaker strut
35 Nosewheel leq door
36 Built-in test equipment (BITE) panel
37 Underfloor control runs
38 Boarding steps/handgrips
39 Flight control augmentation system equipment
40 Canopy emergency release
41 Rear cockpit engine throttles
42 Radar hand controller
43 Rear instrument/display console
44 Starboard intake external compression lip
45 Intake negative incidence position
46 Canopy centre arch
47 Boundary layer bleed air spill duct
48 Ejection seat headrest
49 Seat safety handle/arming lever
50 Weapons System sOfficer's ACES II ejection seat
51 Cockpit pressurisation valves
52 Rear pressure bulkhead
53 Canopy jack
54 Port enqine air intake box construction
55 Variable capture-area 'nodding' air intake
56 Intake high incidence position
57 507 Impgal (610 US gal, 2,309 litre) external fuel tank, centerline pylon mounted
58 Intake pivot fixing
59 Conformal fuel tank forward fairing
60 Fuselage/wing panel sponson fairing
61 Intake duct variable-area ramp doors
62 Intake incidence control jack
63 Cockpit air conditioning plant
64 Canopy hinge point
65 Air conditioning system cooling air exit louvres
66 Forward fuselage fuel tanks: total Intemal capacity 1,681 Impgal (2,019 US gal, 7,643 litres)
67 Intake ramp hydraulic jack
68 Bypass air spill duct, open
69 Bypass door jack
70 Bleed air louvres
71 Refuelling receptacle door actuator
72 Port conforma fuel tank, capacity 624 Imp gal (750 US gal, 2,839 litres) each, port and starboard
73 Conformal tank tangential weapons pylons
74 Ventral main undercarriage wheel bay
75 Port anti-collision light
76 Boom-type air refueling receptacle, open
77 Bleed air supply duct to air conditioning plant
78 Intake ducting
79 Air refuelling feed pipe
80 AN/ALQ-135 ECM system equipment bay
81 Ammunition magazine, 940 rounds
82 Airbrake hinge point
83 Upper UHF aerial
84 Starboard intake bleed-air spill door
85 Cannon muzzle aperture
86 Cannon barrels
87 Starboard anti-collision light
88 M61A-1 Vulcan 20mm cannon
89 Hydraulic rotary cannon drive unit
90 Ammunition feed chute
91 Dorsal airbrake, open
92 Airbrake hydraulic jack
93 Centre-fuselage fuel tanks
94 Machined fuselage main bulkheads
95 Wing/fuselage fuel tank interconnections
96 Fuel tank access panel
97 Airbrake honeycomb core construction
98 Starboard wing integral fuel tank
99 Leading-edge integral fuel tank
100 Starboard wing stores pylon
101 Missile launch rails
102 HF flush aerial panels
103 Wing pylon attachment fitting
104 Fuel system piping to wing pylon
105 Fuel vent box
106 Outer wing panel dry bay
107 Cambered leading-edge panel
108 Forward ECM transmitting antenna
109 Starboard naviqation light
110 Wing -tip fairing
111 Electro-luminescent formation lighting panel
112 Fuel jettison pipe
113 Starboard aileron
114 Aileron hydraulic actuator
115 Starboard plain flap, down position
116 Flap hydraulic actuator
117 Trailing-edge box integral fuel tank
118 Aileron control run
119 Hydraulically driven emergency generator
120 Cooling system intake/bleed air spill duct
121 Intake compressor face
122 Airframe-mounted engine accessory equipment qearbox
123 Jet-fuel starter/auxiliary power unit (APU)
124 Conical intake centre-body
125 Pratt &Whitney FI00-PW·220 afterburning turbofan engine(General Electric F110 alternative fit)
126 Engine bleed air ducting
127 Forward engine support link
128 All-titanium rear fuselage/ engine bay construction
129 Forward engine mounting
130 Fire extinguisher bottle
131 Engine-bay dividing firewall
132 Main engine mounting 'spectacle' frame
133 Afterburner ducting
134 Corrugated inner skin doubler
135 Titanium skin panelling
136 Starboard air system equipment bay
137 AN/ALQ-135 system amplifier
138 Starboard tailplane hydraulic actuator
139 Tailplane hinge arm
140 Boron fibre fin skin panelling
141 Fin leading edge, titanium
142 Starboard fin-tip ECM aerials
143 Anti-collision light
144 Fixed portion of trailing edge
145 Starboard rudder
146 Starboard tailplane
147 Tail boom fairing construction
148 Aft ECM transmitting antenna
149 Variable-area afterburner exit nozzle
150 Nozzle actuating linkages
151 Nozzle shroud fairing
152 Fueldraulic afterburner nozzle actuators
153 Jet pipe central tail lairing
154 Fin spar construction
155 Boron-fibre skin/honeycomb core construction
156 Radar warning antennae
157 Port rear ECM aerial
158 Tail navigation light
159 Port rudder
160 Rudder honeycomb core construction
161 Rudder hydraulic rotary actuator
162 Tailplane pivot fixing
163 Port all-moving tailplane
164 Tailplane honeycomb core construction
165 Boron-fibre skin panelling
166 Tailplane spars
167 Leading-edge dog tooth
168 Port tailplane hydraulic actuator
169 Fin support structure
170 Electro-luminescent formation lighting strip
171 Retractable runway emergency arrester hook
172 Conformal fuel tank tail fairing
173 Ventral air system exhaust duct
174 Port air system equipment bay
175 Engine bleed air primary heat exchanger
176 Port wing trailing-edge box integral fuel tank
177 Flap hydraulic actuator
178 Flap honeycomb core construction
179 Port plain flap
180 Port aileron
181 Aileron hydraulic actuator



**182** Honeycomb core construction
**183** Fuel jettison pipe
**184** Port electro-luminescent
**185** Port navigation light
**186** Forward ECM antenna
**187** Port wing-tip fairing
**188** Outer wing panel rib construction
**189** Machined wing skin/stringer panels
**190** Front spar
**191** Cambered leadling-edge ribs
**192** Wing fuel tank outboard sealing rib
**193** HF flush aerial panels
**194** Machined wing ribs
**195** Titanium wing spars
**196** Port wing integral fuel tank
**197** Wing root rib support struts
**198** Fuel system piping
**199** Wing spar/fuselage attachment pin joints
**200** Main undercarriage leg pivot fixing
**201** Hydraulic retraction jack
**202** Forward breaker strut
**203** Port wing pylon attachment hardpoint
**204** Torque scissor links
**205** Port leading-edge integral fuel tank
**206** Port wing stores pylon
**207** Missile launch rails
**208** Port mainwheel, forward retracting
**209** Mainwheel door
**210** Mk82, 500lb (227kg) HE bombs (26)
**211** Low Altitude Navigation and Targeting Infra-red for Night (LANTIRN) targeting pod
**212** LANTIRN navigation pod, starboard side
**213** Litton forward-looking infra-red (FUR) aperture
**214** Texas instruments terrain following radar
**21** 5 Mk84, 2,000lb(908kg) HE bomb (seven)
**216** Mk83, I,000lb (454kg)HE bomb (15)
**217** AIM-120 Advanced Medium Range Air-To-Air Missile (AMRAAM) (six)
**218** Multiple ejector rack
**219** Mk 20 Rockeye cluster bombs (26)
**220** GBU-10 Paveway II 2,000lb laser-guided bomb (seven)
**221** G8U-12 Pavewey II 500lb laser-guided bomb (15)
**222** GBU-15(V) 2,000lb cruciform wing weapon (CWW) (seven)
**223** AGM-65 Maverick air-to-surface missiles (six)
**224** Triple launch rail unit

Mike Badrocke




**ABOVE Electrical power is provided by left and right generators, each driven by an engine-mounted gearbox.** *(USAF)*

LEGEND

AC POWER
DC POWER
EXTERNAL AC POWER
EMERG AC POWER
EMERG DC POWER
START POWER
CONTROL POWER
MECHANICAL CONNECTION

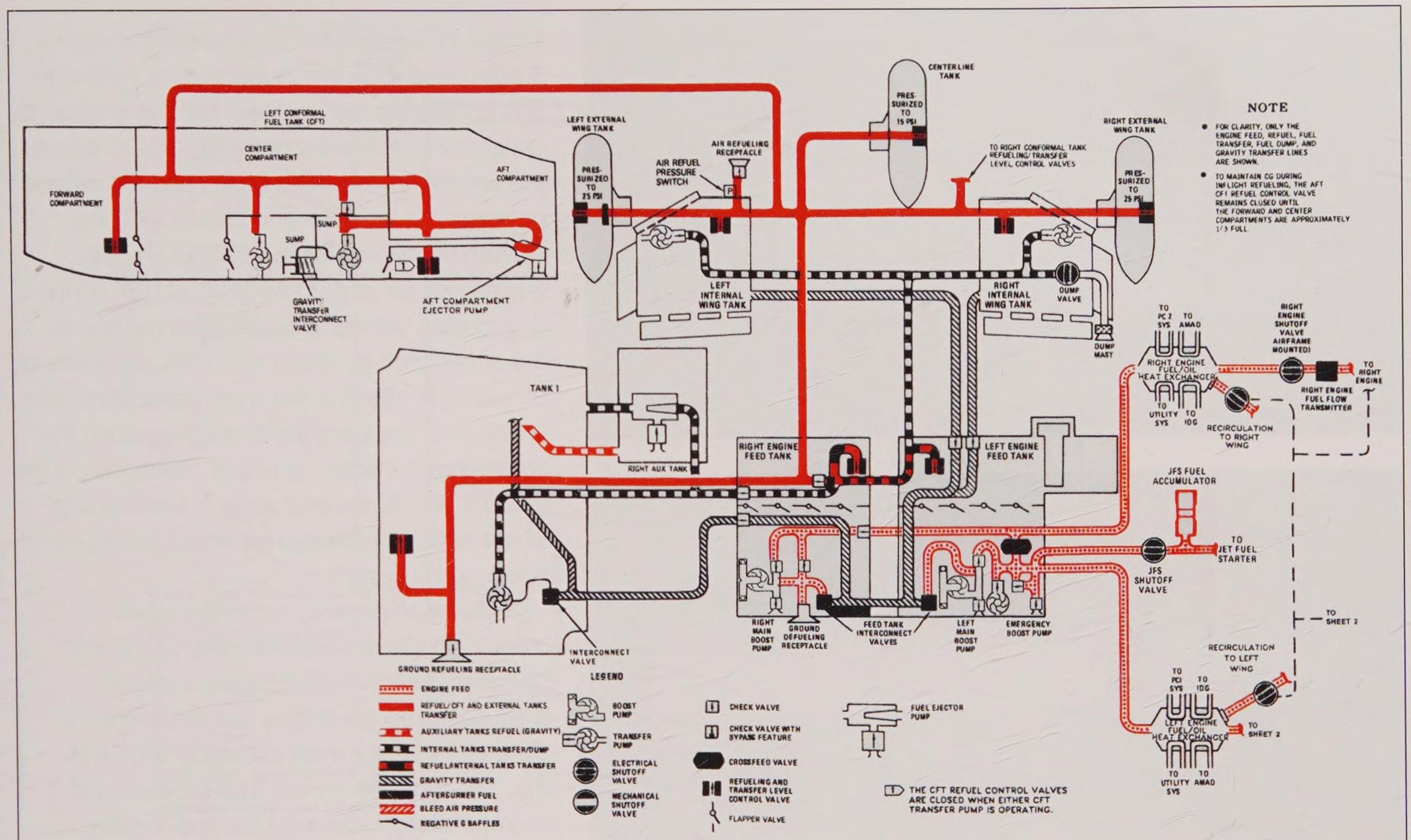
## AC electrical power

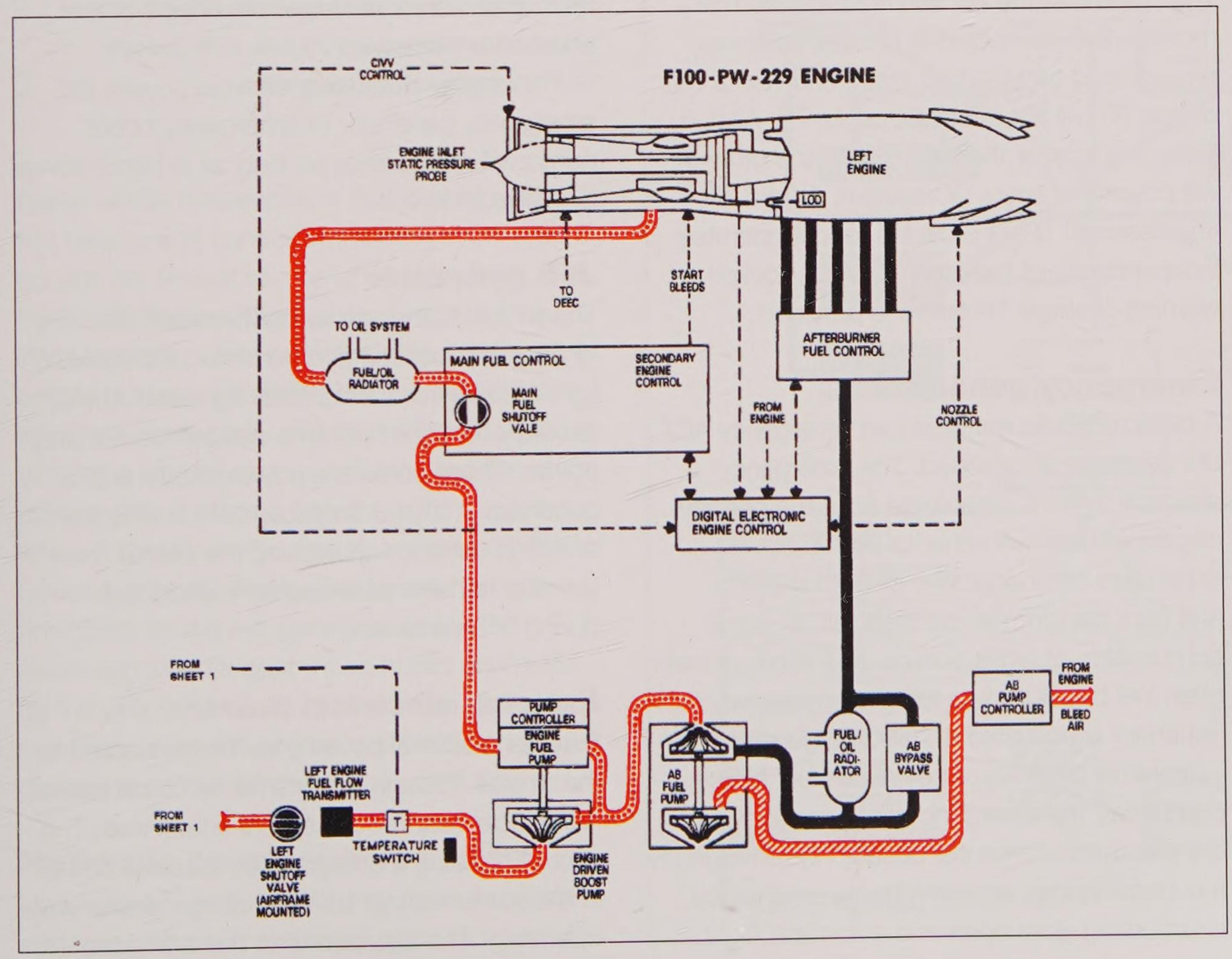
Two AC generators are the primary source of electrical power. The two generators are connected for split bus nonsynchronised operation. This means that with both generators operating each generator supplies power independently to certain aircraft buses. If one generator fails, it drops off the line. At the same time, power from the remaining generator is provided to the buses of the failed (or turned-off) generator. Current limiters are provided to prevent a fault in one generator system from shutting down both generators.

Either generator is capable of supplying power to the entire system. Each generator is activated automatically when the appropriate control switch is in the 'ON' position, and the generator is connected to the appropriate buses when voltage and frequency are within prescribed limits (approximately 56% engine rpm).

A protection system within the generator control unit protects against damage due to undervoltage, overvoltage, over- and under-frequency, feeder faults and generator-locked rotor. If a fault or malfunction occurs, the generator control unit removes the affected generator from the appropriate buses. Except for an under-frequency condition, the control switch of the affected generator must be cycled to bring the generator back on the line after the fault or out-of-tolerance condition clears. If the generator drops off the line due to under-frequency and the prescribed frequency is restored, the generator will come back on the line automatically.

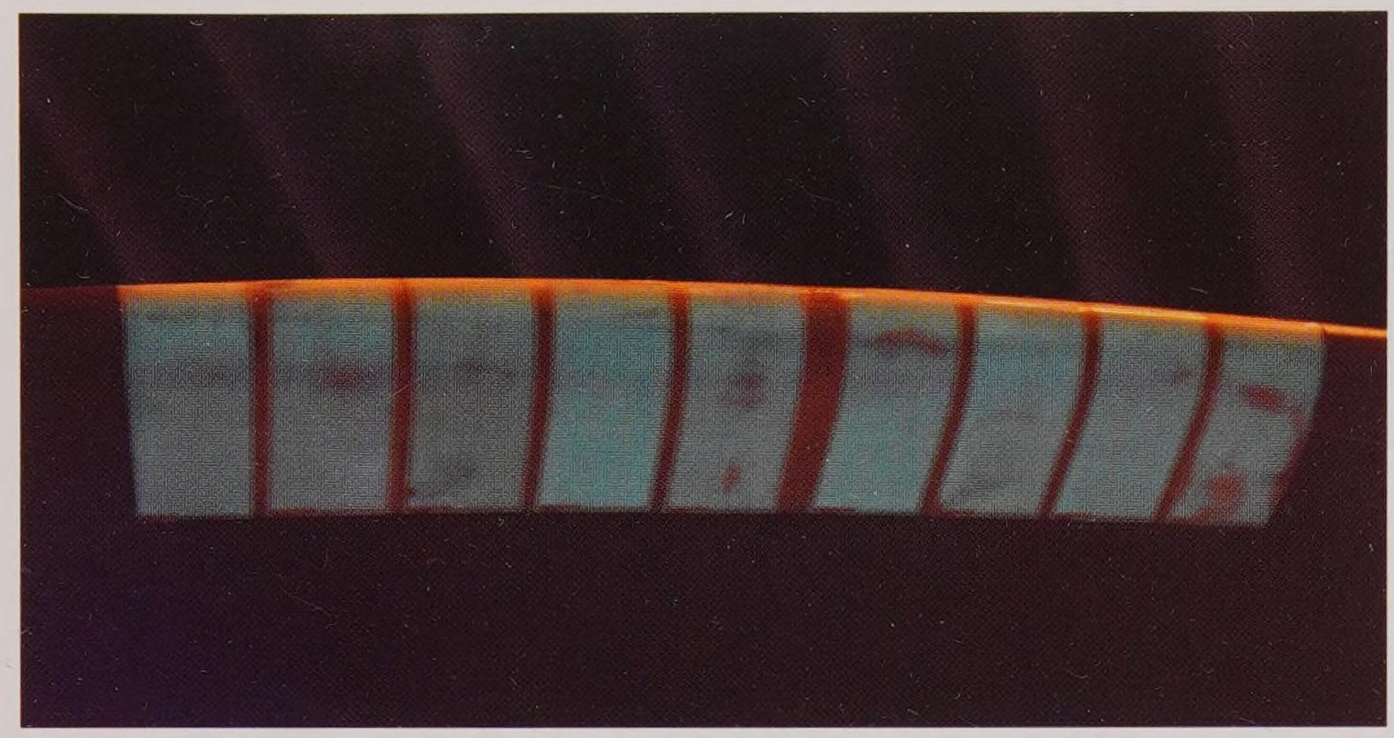
A generator may be removed from the appropriate buses at any time by placing the generator control switch to 'OFF'. Indicator lights, labelled 'L GEN' and 'R GEN', are on both caution light panels. These lights come on whenever their respective generator drops off the line with power available on the essential 115 VAC bus to illuminate the lights.




**ABOVE AND LEFT**

**The F-15 fuel system feeds the engines from three external tanks, the conformal fuel tanks (if fitted) and the internal fuel tanks.** *(USAF)*



**ABOVE Formation strip lights on the wingtip and fuselage allow night formation flying while retaining some element of reduced visual signature.** *(Steve Davies/ FJPhotography.com)*

## DC electrical power

Three transformer-rectifiers (TR) are provided. The outputs of the left and right transformer-rectifiers are connected in parallel; however, protection is provided so that a short on a bus of one TR will not affect the other TR. Also, if either the right or the left TR fails, the other TR will power the entire DC system. A third TR (the essential TR) is provided, and it operates independently of the other two. No cockpit warning of single TR failure is provided.

## Emergency generator

A utility hydraulic motor-driven emergency AC/DC generator is provided. The emergency electrical system is separate from the primary electrical system. If either or both main generators are inoperative or both the left and right transformer-rectifiers fail, or some combination of faults occurs, or if either or both main fuel boost pumps fail, the emergency generator is activated. If only one generator is inoperative or either or both main fuel boost pumps fail, the emergency generator powers the emergency/essential buses only (emergency fuel boost pump, arresting hook, emergency air-refuelling door open and automatic flight control system/control augmentation system). If both generators are inoperative or both right and left transformer-rectifiers fail, the emergency generator supplies the essential AC/DC buses, the emergency/essential buses and the ground power switch number one 28-volt DC bus.

With the aircraft on the ground and the emergency generator switch in 'AUTO' during engine start without external electrical power, the emergency generator automatically shuts off 30 seconds after the first main generator comes on the line. The purpose of shutting down the emergency generator is to limit operation on the ground. The 30-second delay is to allow time to check the emergency generator/emergency boost pump system.

With the emergency generator switch in 'AUTO' on the ground, both the 'EMER BST ON' and 'BST SYS MAL' lights come on in situations (single engine taxi, first engine start, etc) where a main generator is off the line. The lights will go out when the second main generator comes on the line. If either generator fails or is turned off following the initial 30-second time-out, the 'EMER BST ON' and 'BST SYS MAL' lights will illuminate immediately and remain on until weight off wheels or the situation is corrected.

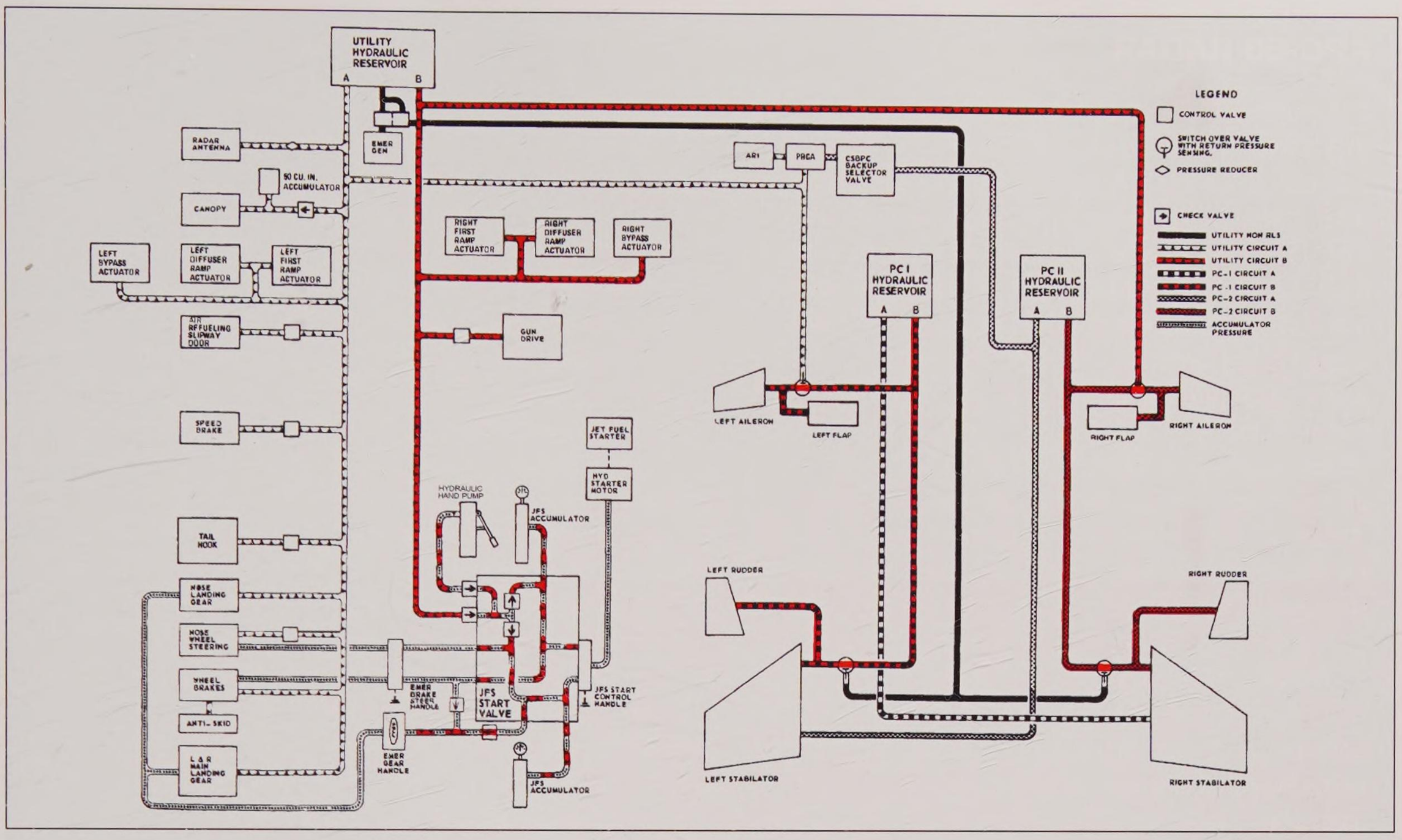
For engine start using external power, the emergency generator or emergency boost pump will not operate as long as external power is connected.

## JFS generator

The jet fuel starter generator provides JFS ignition and control, and with the 'JFS READY' light on, intercom, front utility light and AMAD (auxiliary mounted airframe device) fire warning power. These items are powered by the JFS generator until JFS shutdown. If the JFS start switch is used for shutdown, the AMAD fire warning remains powered for a short time during JFS rundown.

## External electrical power

External electrical power may be connected to the aircraft through an external electrical power receptacle near the nose-gear wheel well. The aircraft buses are energised by external power in the same manner as if a main generator were operating. The exceptions to this are those

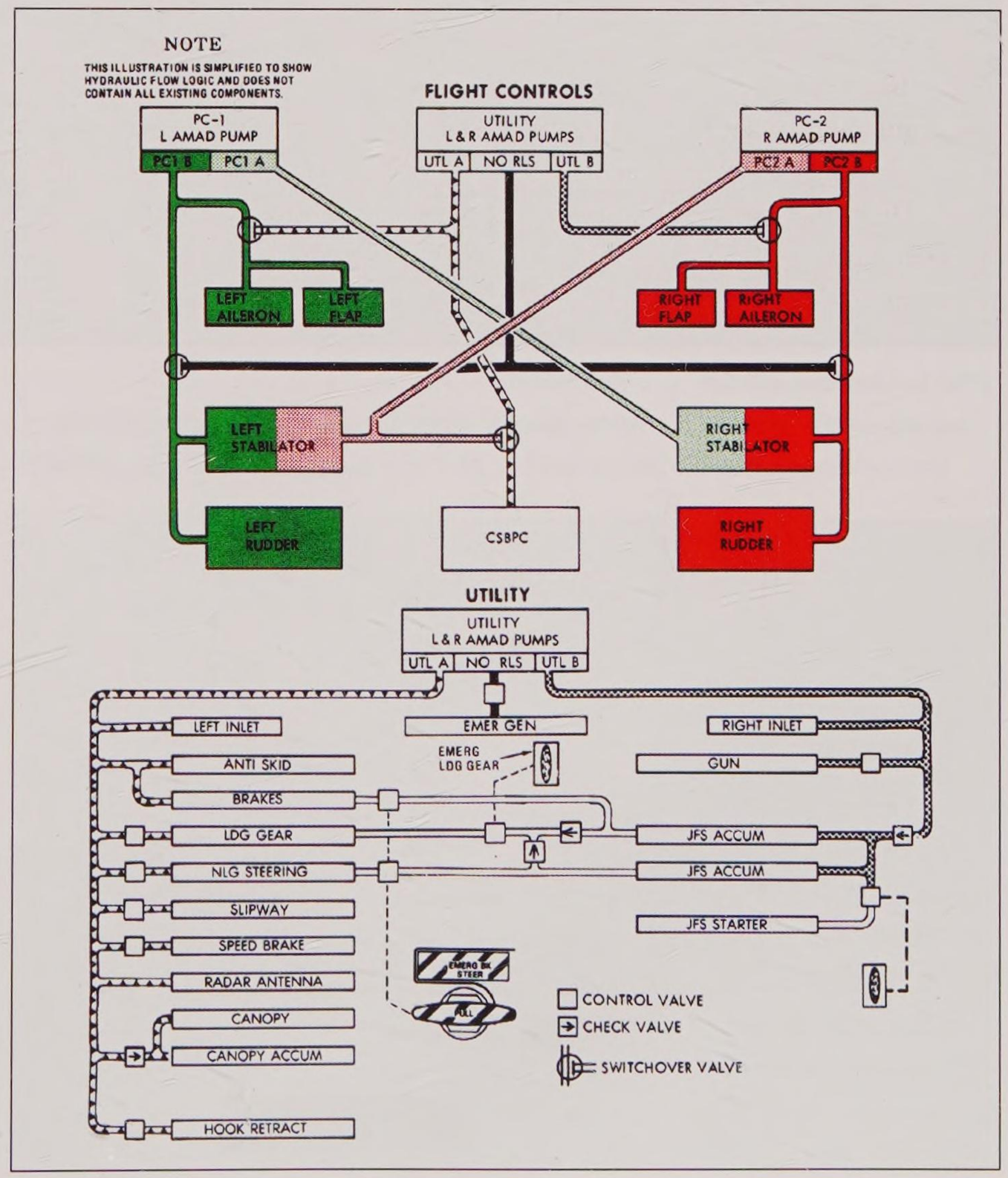



**ABOVE AND RIGHT PC1, PC2 and utility hydraulics circuits provide redundancy in case one of the PC systems fails. As this schematic shows, PC1 and PC2 independently power different flight controls.** *(USAF)*

buses which furnish power to systems which do not have on-off control switches and/or require cooling air. Power can be applied to these buses by the use of ground power switches. With external power on the airplane, if the left engine is started first, the complete electrical system automatically switches to internal power when the left generator comes on the line. If the right engine is started first, the right generator, when it comes on the line, energises only the buses it normally feeds. The buses normally energised by the left generator remain on external power (except those buses energised by the JFS generator) until the external power is removed or the left engine is started and the left generator comes on the line.

## Hydraulic power supply system

Hydraulic power is supplied by three separate systems with each system divided into two or



## APG-63 RADAR

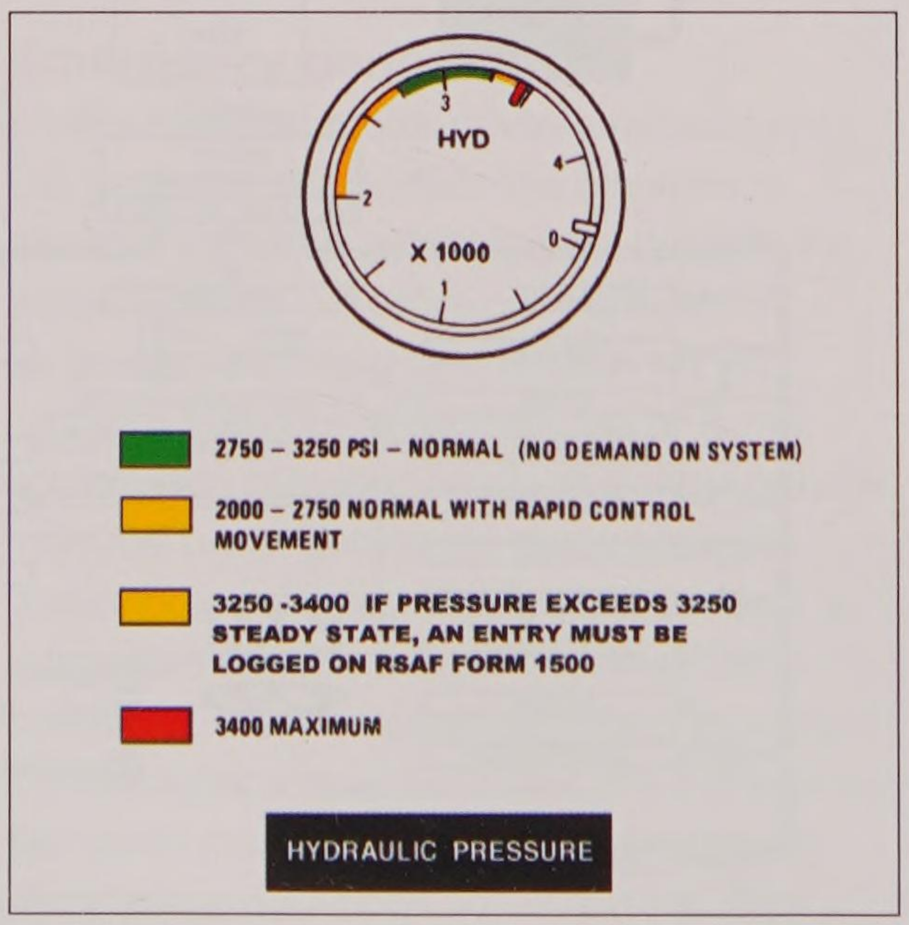
The Hughes APG-63 is a high-frequency, X-band (8–12GHz) PD radar designed primarily for air-to-air combat. The original APG-63 consisted of a planar array (flat faced) antenna, an analog processor, digital signal processor, radar data processor, power supply, exciter, transmitter, receiver and radar set control panel in the cockpit. It provides target range, range rate (closure), antenna angles (azimuth and elevation) and angular rates (antenna movement to track the target) to the CC, for computation of selected weapon attack parameters. The CC presents the results as synthetic symbology to the pilot on the VSD in 'B-Scope' format, which is a top-down view that shows range versus azimuth, with digital information displayed near the target 'blip' and along the 'range bar' at the edge of the scope.

The original 'vanilla' APG-63 offered a variety of radar functions broken down into search, acquisition and special modes. The primary 'radar look' was long-range search (LRS), which was optimised by using alternating sweeps (interleaved 'bars') of high- and medium-PRFs whilst scanning as far out as 160nm (displayed on 160, 80, 40 and 20nm scopes). Short-range search (SRS) mode used MPRF only, expanded vertical volume and shorter range (ten-mile scope). Velocity search was a long-range surveillance mode that used HPRF exclusively and presented targets in a closure vs azimuth format. It was optimised for early detection of very fast targets such as the MiG-25.

Finally, 'pulse' was originally a low-PRF back-up to all A/A modes (except Super Search), but was useable only in a 'look up' environment.

Four automatic acquisition (auto-acq) modes – Auto-Guns, Super Search (SS), Boresight (BST) and Vertical Scan (VS) – all used a 10nm display. The auto-acq modes would, as the name suggests, automatically lock on to the first target they detected in their scan pattern, and were therefore extremely valuable in close-in, visual manoeuvring against an enemy fighter. Special modes included Manual Track, Visual Identification (VI), Beacon, Sniff and Flood. Manual track allowed the pilot to observe a target detected in a search mode, but used a much tighter scan pattern (3°/2-bar) that hopefully would not trigger the enemy's EW gear. VI mode was the antithesis of this, as it locked-up the contact and then guided the pilot through HUD and VSD displays to fly an intercept profile which ended low and just off the target's wing, facilitating a VID of the target. Beacon was a receive-only mode which allowed vectoring to an aircraft, such as a tanker, or a ground position with an electronic beacon transmitting on a certain frequency. Sniff was a listen-only mode to reduce F-15 radar emissions in order to improve detection of jamming platforms and other airborne radars. Flood provided range only information out to 2nm by transmitting HPRF using the 'flood horn'.

more circuits. Reservoir level sensing (RLS) is employed in all three systems for the purpose of isolating a leak. When a leak develops in a circuit a valve senses the reservoir level and shuts off the affected circuit. Through this method the maximum number of circuits remain operable.




**RIGHT The 'peanut gauge' for the hydraulics pressure levels is so named because of its tiny size.** *(USAF)*

### PC systems

Both the Power Control (PC) 1 pump and PC2 pump operate at a pressure of 3,000psi. Each PC system is divided into a circuit A and a circuit B.

### Utility system

The utility system has a left pump which operates at a pressure of 3,000psi and a right pump which operates at a pressure of 2,775psi. The utility system is divided into a circuit A, circuit B and a non-RLS circuit.

**FAR LEFT** **Tiny holes in the top of the intake ramps allow air pressure to diffuse during flight, ensuring a smoother flow of air to the engine.** *(Steve Davies/ FJPhotography.com)*

**LEFT** **The counter-munitions dispensers on the underside of the fuselage have blanking plates when not in use, as is the case here for three of the four bays on this side. The red plugs denote live flares.** *(Steve Davies/ FJPhotography.com)*

**LEFT** **Larger red plugs indicate larger flares.** *(Steve Davies/ FJPhotography.com)*

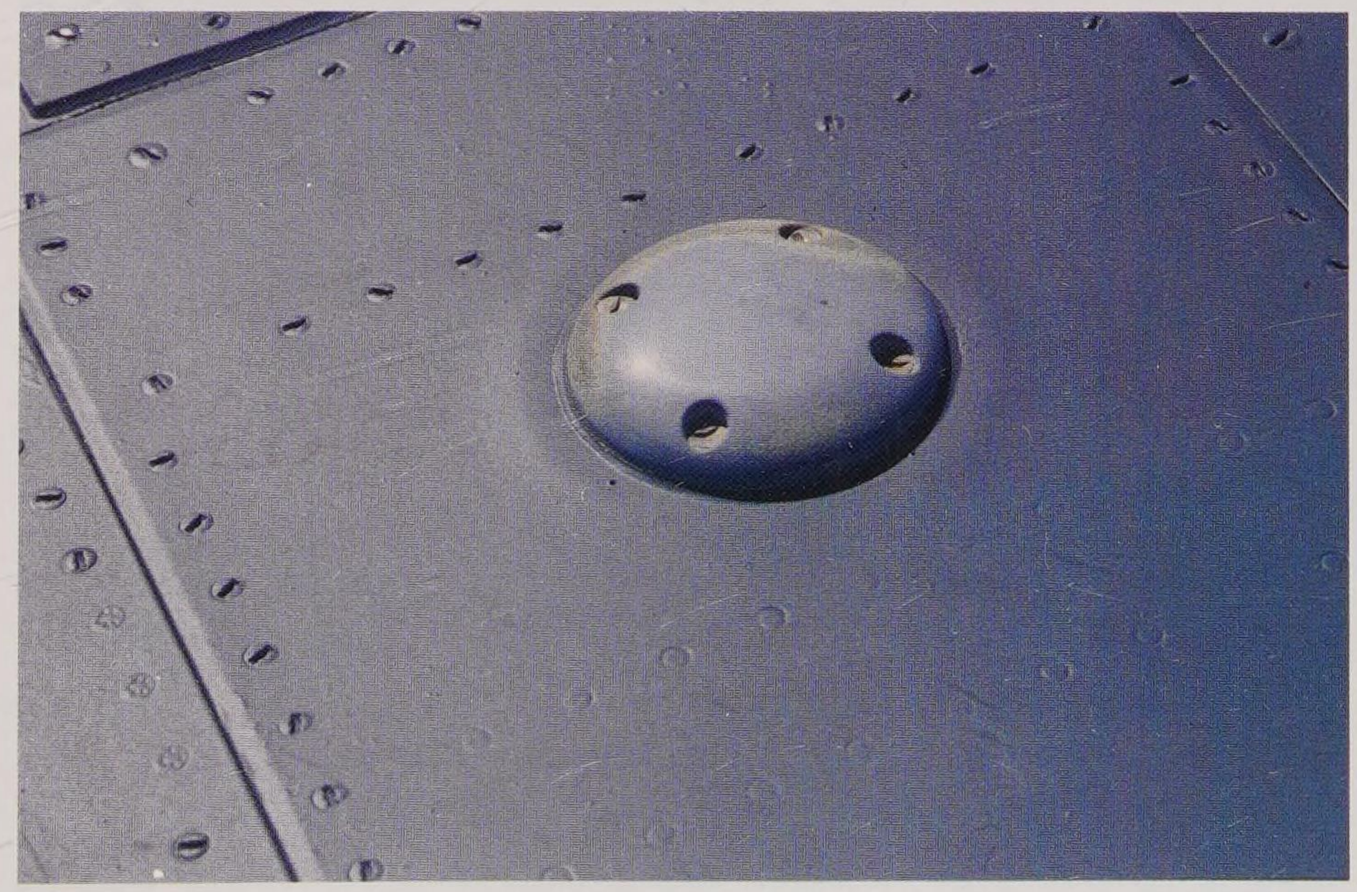
## Reservoir level sensing

If a leak occurs in any circuit, the reservoir level of that system (PC1, PC2 or utility) drops and circuit A is shut off. If the leak is in circuit B, the reservoir level continues to drop causing circuit A to be restored and circuit B is shut off. In the case of the utility system with a non-RLS circuit leak, circuit A is shut off then restored as circuit B is shut off. However, if flight is continued, a complete utility failure will eventually occur as indicated by zero pressure on the utility hydraulic gauge.

## Switchover valves

Five hydraulic switchover valves provide backup hydraulic pressure to the flight controls and control stick boost/pitch compensator (CSBPC). Each valve monitors the pressure in the primary and the backup hydraulic supply circuits. If there is a drop in the primary circuit pressure, the valve tests the downstream component(s) for leaks prior to switching to the backup circuit. If no leak is detected, the valve allows the backup circuit to power the component(s). If a leak is detected, the valve remains in the test mode and backup circuit pressure is not supplied to the affected component(s). Flight control surfaces should be visually checked for proper movement after any failures involving PC-1B or PC-2B circuits.

**BELOW** **This inconspicuous disc on the top of the fuselage is actually the antenna for the embedded GPS system.** *(Steve Davies/ FJPhotography.com)*



## Hydraulic pressure indicators and caution lights

Three hydraulic (HYD) pressure gauges on the upper right corner of the instrument panel display PC1, PC2 and utility hydraulic system pressures.

An amber HYD light on the caution lights panel and the 'MASTER CAUTION' light come on when any hydraulic systems caution exists. The appropriate caution display – PC1 A, PC1 B, PC2 A, PC2 B, utility (UTL) A and UTL B will be displayed on the MPD/MPCD when their respective RLS valve actuates to shut off that circuit. The 'L PUMP' or 'R PUMP' caution is also displayed on the MPD/MPCD when the respective utility hydraulic pump output pressure is low. An indication of a PC pump failure or low pressure is displayed on the MPD/MPCD as 'PC1 A' and 'PC1 B' or 'PC2 A' and 'PC2 B'. Resetting the 'MASTER CAUTION' light will not extinguish the HYD light or the associated caution on the MPD/MPCD.

## Landing gear system

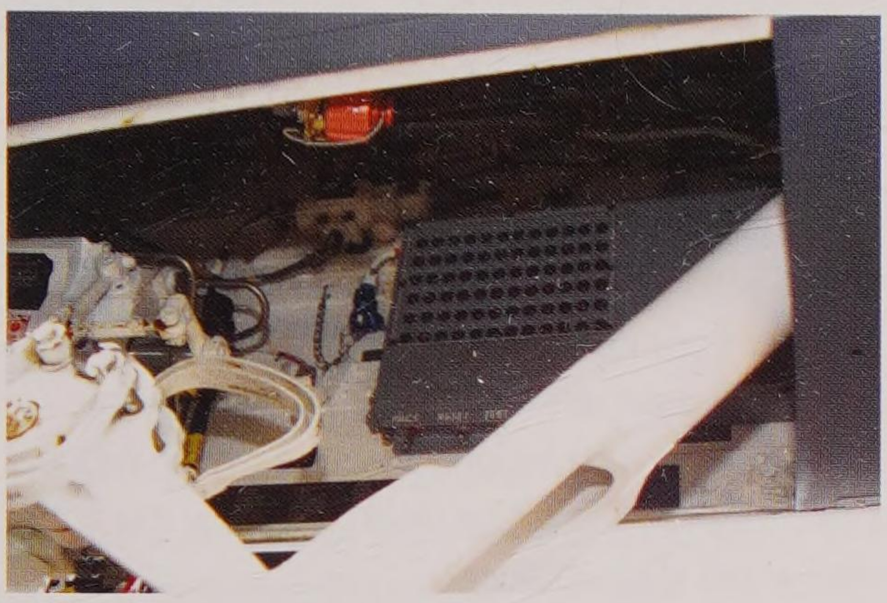
The gear is electrically controlled and hydraulically operated. While weight is on the gear, the gear cannot be retracted. When the main and nose gear are extended, the forward door(s) will be closed.

Nose gear steering (NGS) is a full-time mechanically controlled (front and rear cockpit rudder pedals) hydraulically powered (UTL A pressure) system that features dual authority steering ranges consisting of a normal range (15°–30° left or right) and a manoeuvring range (45° left or right). The steering system automatically engages whenever the nose gear strut is compressed by the weight of the aircraft and provides normal steering authority range. The manoeuvring range is selected by pressing the 'NGS' button on the front cockpit control stick. The nose gear steering system may be disengaged from either cockpit by pressing and holding the paddle switch on the control stick.

With the system disengaged, the nose wheel becomes free-swivelling and may be swivelled 360°. When the paddle switch is released, the system will not re-engage if the nose gear has rotated more than approximately 56°. However, if the steering is engaged with the nose gear rotated beyond 45° the nose gear will be

**RIGHT The F-15E's main landing gear and wheels are 'beefed up' to accommodate a maximum take-off weight of 81,000lb.** *(Steve Davies/ FJPhotography.com)*

**FAR RIGHT Just forward of the main gear are the main gear doors (which retract once the gear is down and locked). For the Strike Eagle, these doors were given a bulge to accommodate the strengthened main landing gear wheel.** *(Steve Davies/ FJPhotography.com)*



**FAR LEFT The nose gear retracts forward...** *(Steve Davies/FJPhotography.com)*

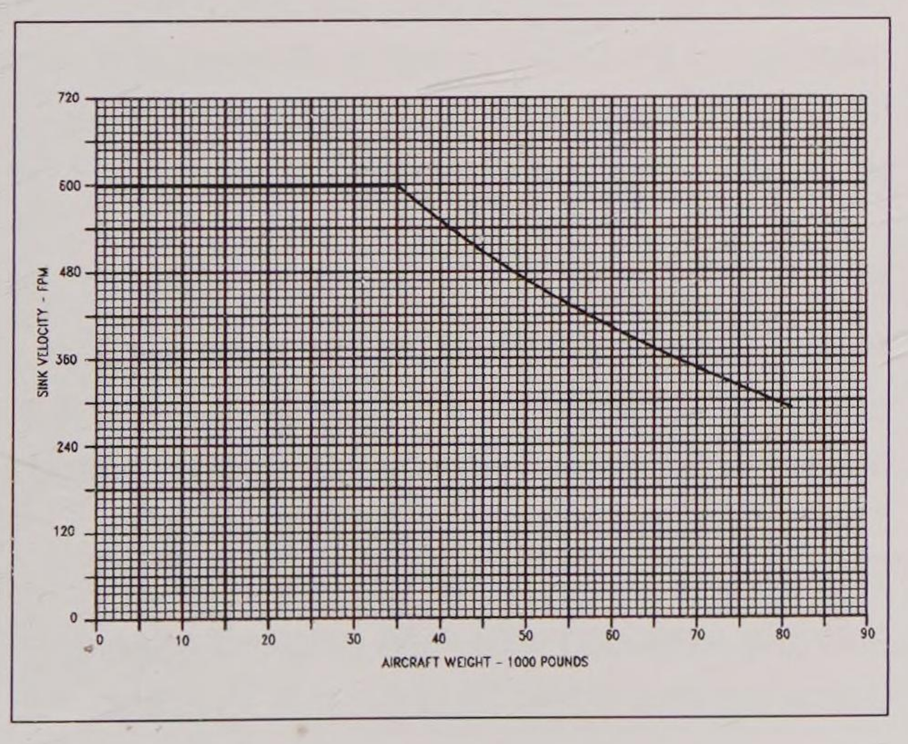
**LEFT ...and a mass balancer is installed just below the chrome oleo extension, in order to prevent nose wheel 'shimmy' (oscillation) during high-speed taxi.** *(Steve Davies/FJPhotography.com)*

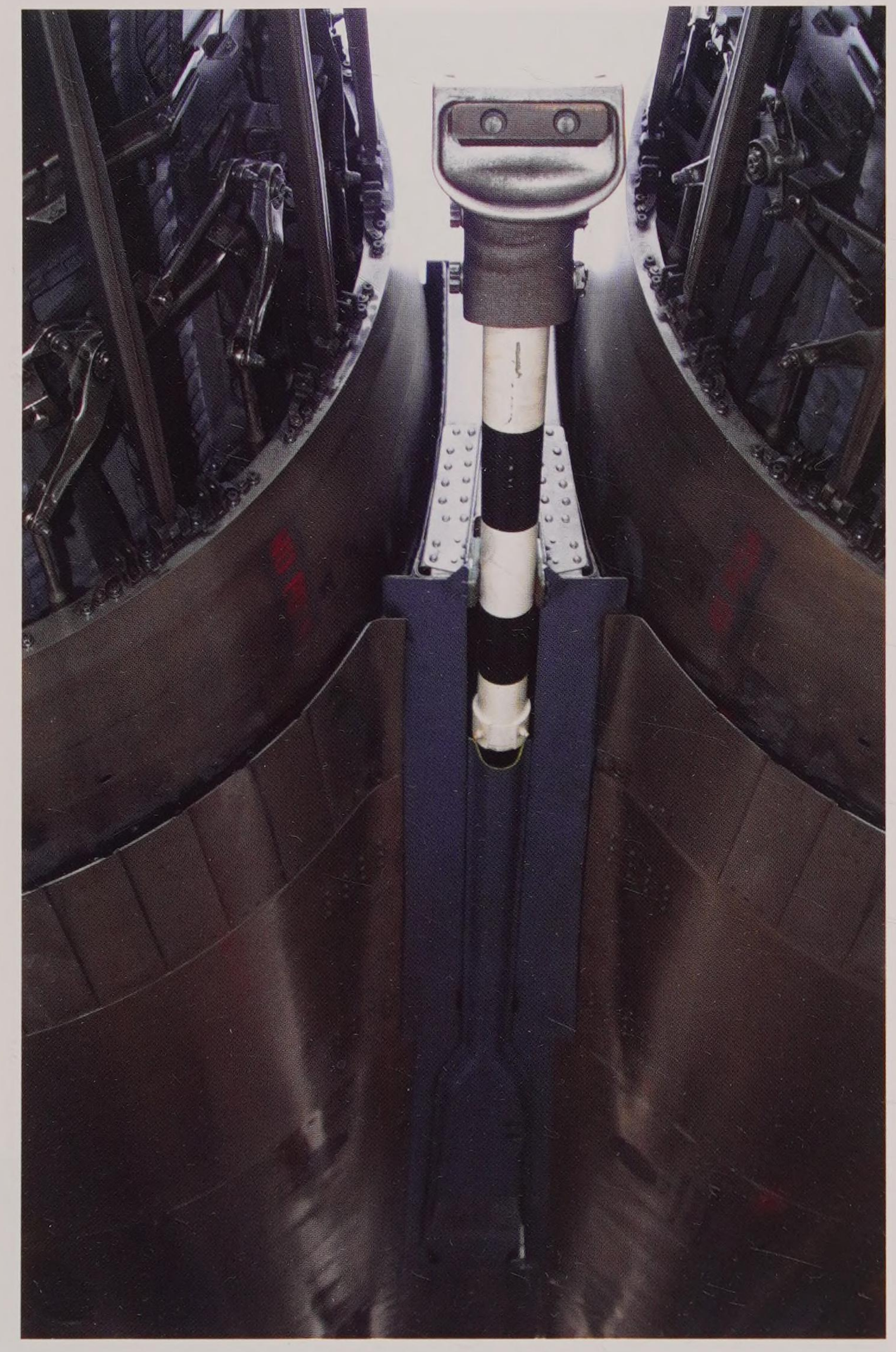
**FAR LEFT Circuit breakers inside the nose-wheel door give the crew chief quick access to the status of critical systems.** *(Steve Davies/FJPhotography.com)*

immediately driven back to the 45° position. During taxi, when centring action reduces the angle below approximately 45° the nose gear steering system will re-engage. On take-off, nose gear steering is disengaged when the nose gear strut extends.

**RIGHT A cannibalised F-15E sits in a hardened shelter at RAF Lakenheath, devoid of CFTs. This view shows off the relatively narrow track of the undercarriage.** *(Steve Davies/FJPhotography.com)*

**BELOW The allowable landing sink rate for the F-15E.** *(USAF)*





**ABOVE For emergency stopping, the Eagle has an arrestor hook that can be lowered to catch an arrestor cable.** *(Steve Davies/ FJPhotography.com)*

## Brake system

The main landing gear wheels are equipped with hydraulically powered brakes operated by toe action on the rudder pedals. An anti-skid system is incorporated in the normal brake system to provide maximum deceleration with controlled wheel skid. An emergency brake system provides JFS hydraulic accumulator pressure to power the brake system in the event of loss of UTL A which normally powers the system. Anti-skid protection is not available on the emergency brake system. A holding brake relieves the aircrew from maintaining pressure on the brake pedals when the aircraft is stopped for long periods of time.

## Anti-skid

The anti-skid system is electronically controlled by a three-position switch in the front cockpit on the miscellaneous control panel. An 'ANTI-SKID' caution and the 'MASTER CAUTION' light will come on whenever the landing gear is down and a system failure is detected. A touchdown protection circuit (with anti-skid on) prevents hydraulic pressure from being applied to the brakes until both main wheels spin up.

The brake pulser provides main tyre skid control in the event anti-skid braking is not available. Skid control effectiveness deteriorates below 30kt; therefore, heavy braking below 30kt may result in locked wheels. The pulser may also be selected manually by the anti-skid switch. When the pulser system is activated, applied brake pressure is repeatedly interrupted to the wheel brakes. This provides pulsating braking action which reduces the probability of tyre blowout from locked wheels. This also prevents bringing the aircraft to a complete stop on the brake pulser. After touchdown, the aileron rudder interconnect (ARI) will be disengaged by the anti-skid wheel spin-up signal.

With the anti-skid switch in 'OFF' or 'PULSER', the ARI will be disengaged any time the landing gear handle is down. When the anti-skid is inoperative and for some anti-skid detected malfunctions, the ARI will remain engaged at wheel spin-up, adversely affecting crosswind landing characteristics. Placing the anti-skid switch to 'OFF' or 'PULSER' will ensure ARI disengagement.

The 'MASTER CAUTION' light and 'ANTI-SKID' caution do not depend on the position of the landing gear circuit breaker in the front cockpit. However, if the landing gear circuit breaker is pulled or popped, the automatic selection of the brake pulser is disabled and 'PULSER' must be manually selected in order to obtain pulser and disengage ARI.

## Speed brake

A speed brake is located on the upper surface of the centre fuselage just aft of the canopy. It is electrically controlled and hydraulically operated. The speed brake can be positioned to any intermediate position between fully retracted and fully extended with AOA (angle of attack) below approximately 25 units. If AOA is above

25 units, the speed brake will not extend when selected. If the speed brake is extended, it will automatically retract when AOA increases through 25 units.

If the flight control computer (FCC) detects a failure in the AOA system ('AOA FAIL' is displayed), the speed brake retracts, if extended. If the AOA failure occurs with the speed brake closed, it cannot be extended. Following automatic retraction of the speed brake, when AOA is reduced, the speed brake will automatically extend provided the speed brake switch is in the 'OUT' position.

The speed brake switch has three positions and is located on the inboard throttle. The switch will remain in any selected position. The rear cockpit speed brake switch will override any position selected by the front cockpit. It is spring-loaded to the hold (centred) position. When the rear cockpit switch is released to hold, control is returned to the front cockpit.

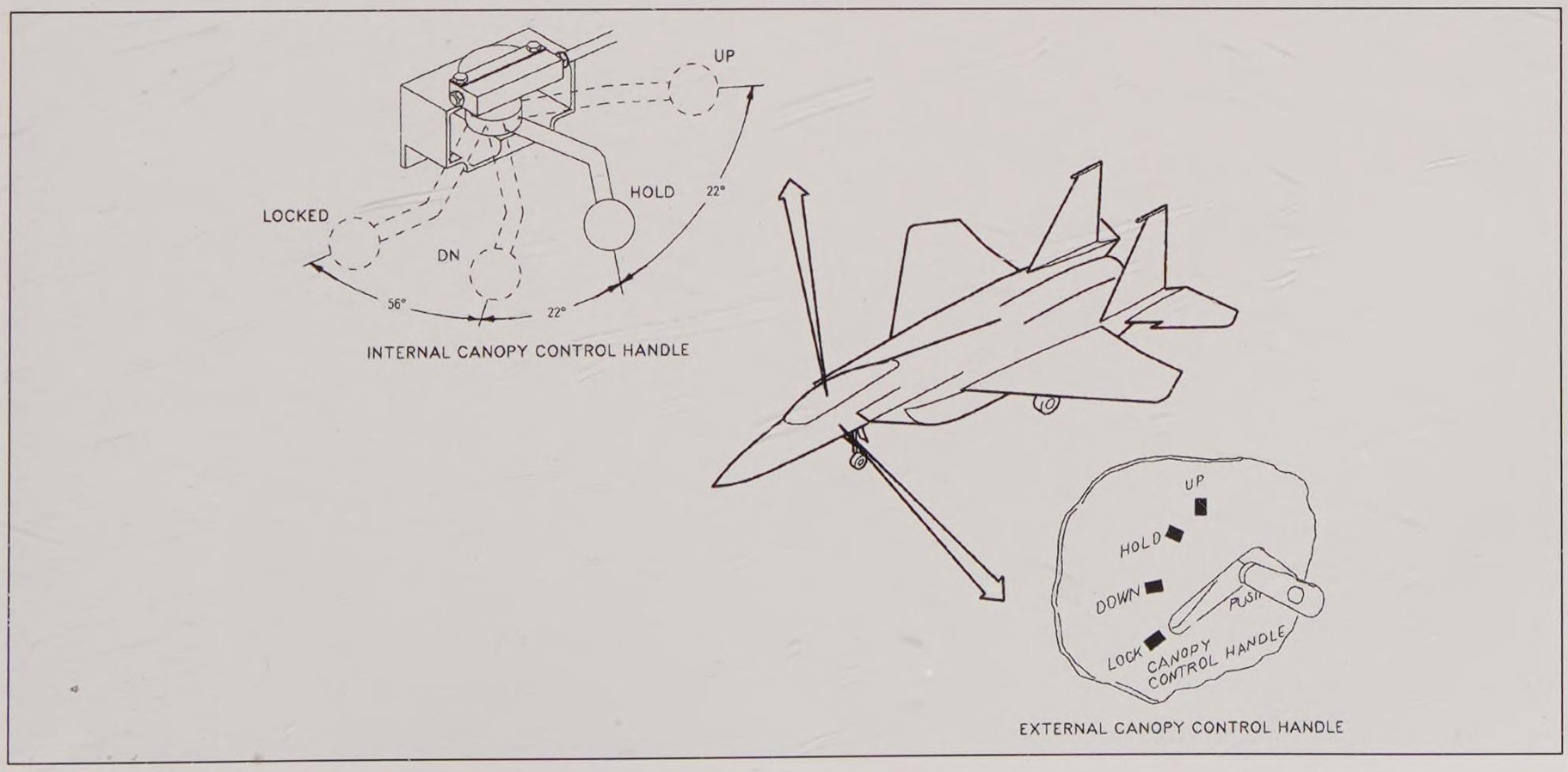
**LEFT The speed brake, controlled by a throttle-mounted switch, is mounted dorsally. A schedule based on airspeed determines how far it can open during flight.** *(Steve Davies/ FJPhotography.com)*

## Flight control system

The aircraft primary flight control surfaces consist of conventional ailerons, twin rudders and stabilators (which are capable of symmetrical or differential movement). Hydraulic actuators are used to position the control surfaces. The inputs to the hydraulic actuators are from a hydromechanical system and an electrical system called the control augmentation system (CAS).

The hydromechanical system and the CAS normally work together, but either system alone is capable of providing sufficient aircraft control for flight. Spring cartridges provide simulated aerodynamic forces to the control stick and rudder pedals. The spring cartridges have trim actuators which actually move the neutral positions and thus the control surfaces.

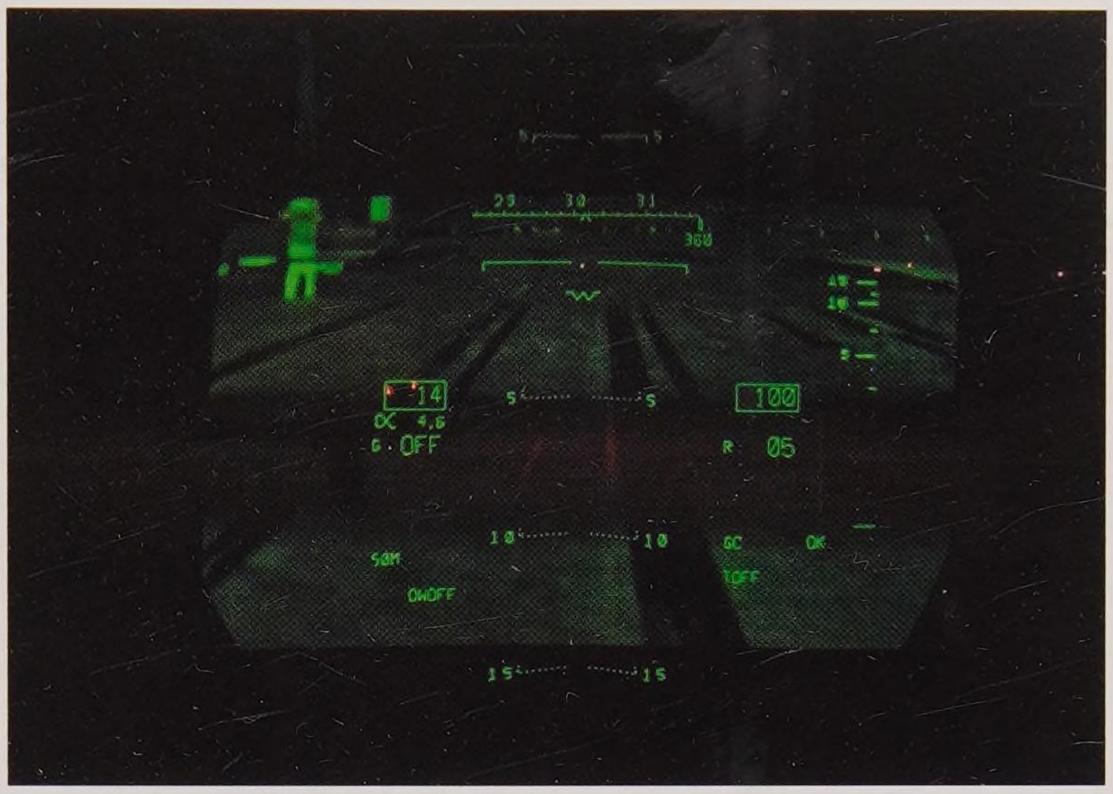
The front cockpit control stick consists of a stick grip and force transducer, and contains seven controls: an autopilot/nose gear steering disengage switch (paddle switch), nose gear steering/weapons button, a trigger, a weapon release button, a trim switch, an auto acquisition button and a castle switch.



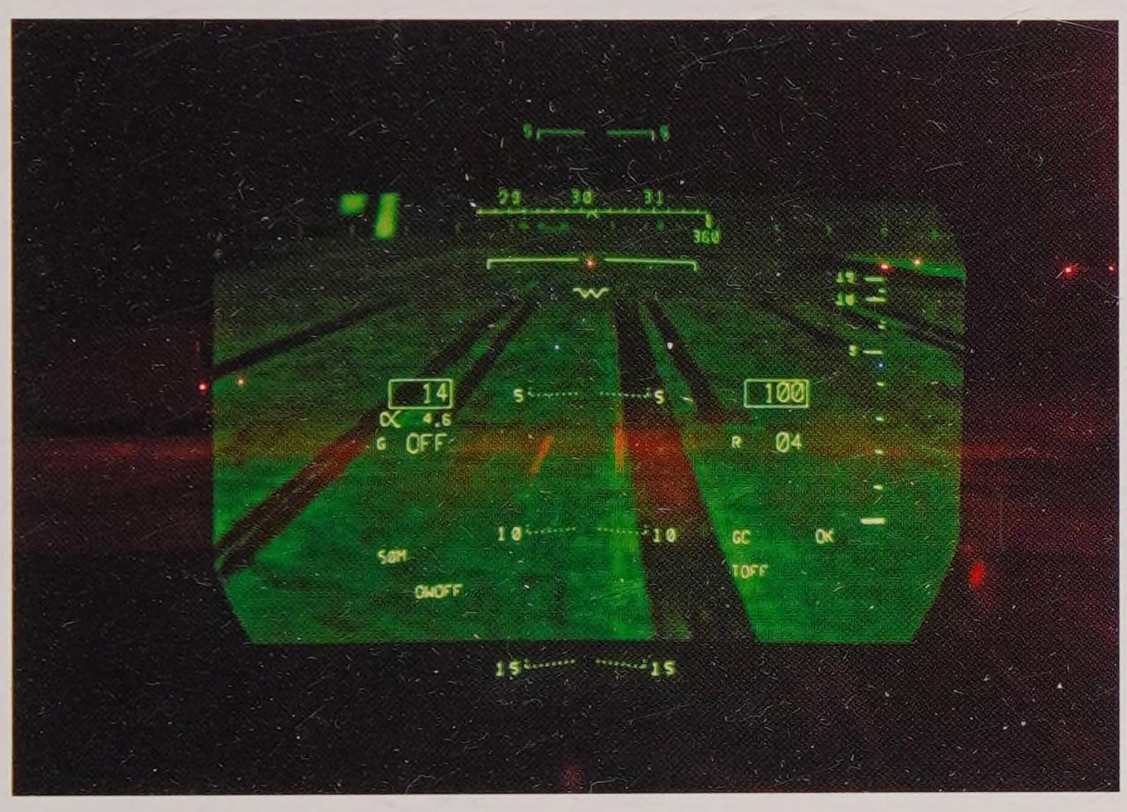

**LEFT Access to the cockpit is gained via an internal or external ladder. Controls inside and outside the cockpit allow the canopy to be raised and lowered.** *(USAF)*

**The F-15E front cockpit is dominated by three large multi-purpose displays (one of which is colour) and the impressive wide field of view HUD.**
*(Steve Davies/FJPhotography.com)*

**ABOVE With the use of some green filters placed strategically over certain light sources, the F-15E's cockpit is night-vision goggle compatible.** *(Steve Davies/FJPhotography.com)*

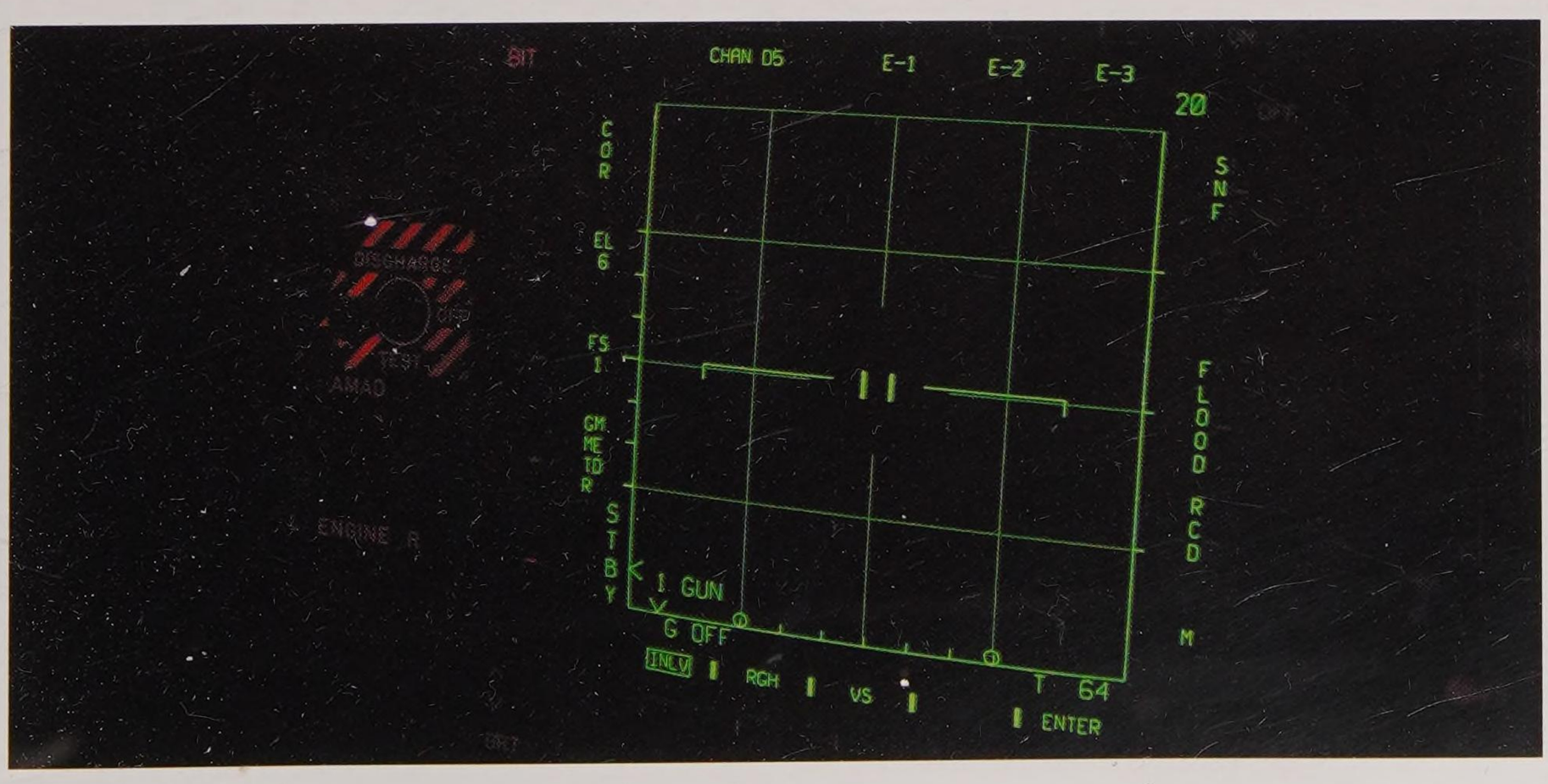



**ABOVE The Strike Eagle's WFOV HUD with the forward-looking IR image from the nav pod displayed.** *(Steve Davies/FJPhotography.com)*

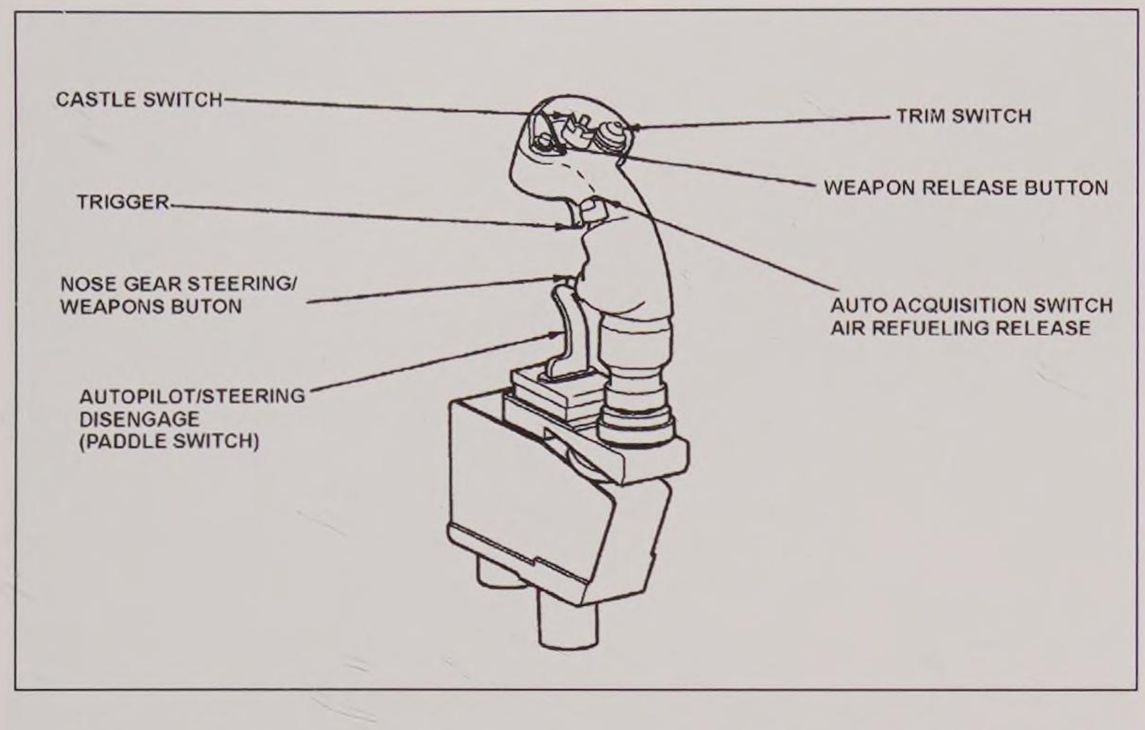



**ABOVE As a man drives up and gets out of a vehicle, he is clearly visible in the left side of the image.** *(Steve Davies/FJPhotography.com)*

**ABOVE The rear cockpit of the Strike Eagle boasts four displays, two of which are colour. Here, the two central displays show the radar and the HUD repeater.** *(Steve Davies/FJPhotography.com)*

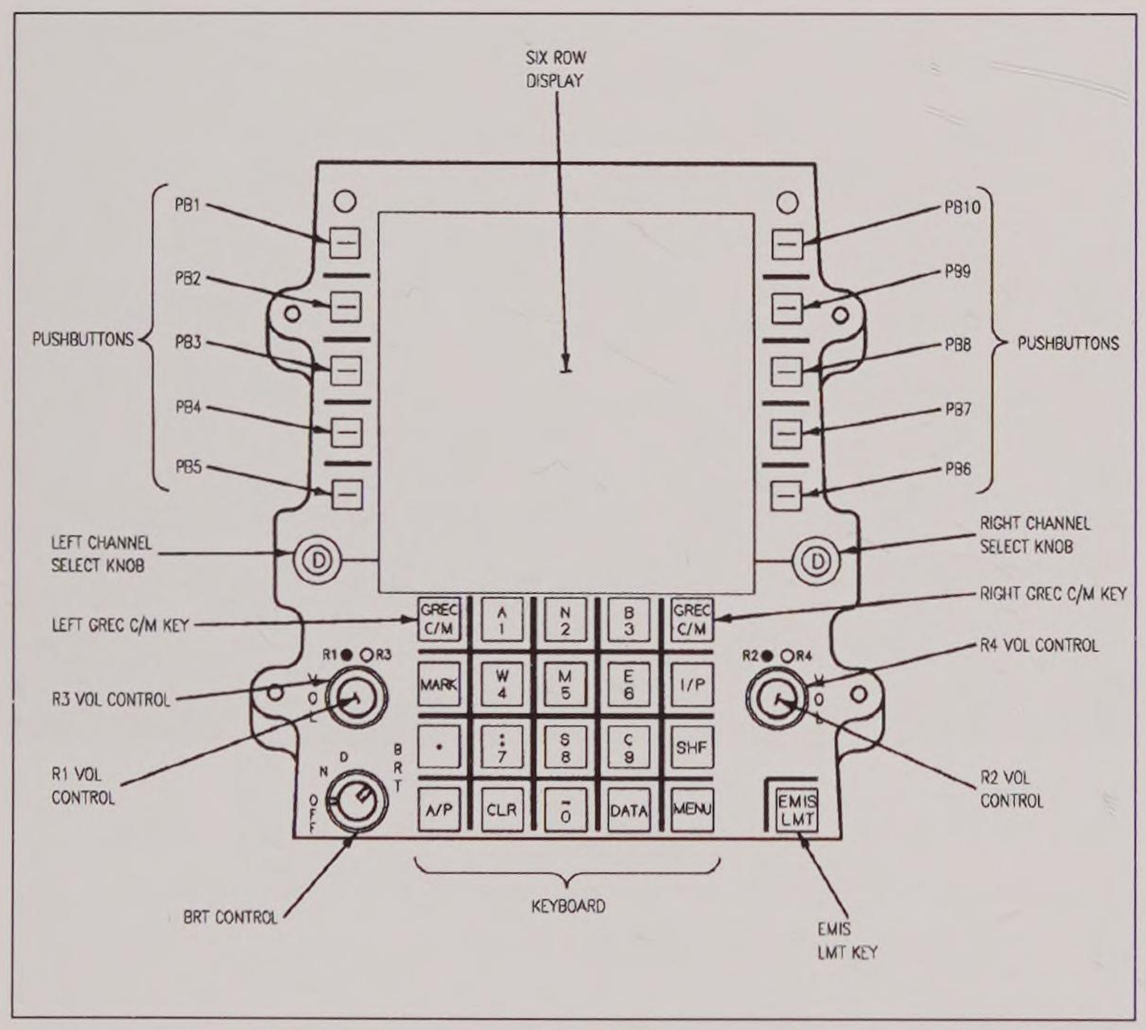



**LEFT The APG-70 radar display in air-to-air mode. Push-buttons on the bezel of each display ailow the crewmember to interact with the aircraft's systems.** *(Steve Davies/FJPhotography.com)*



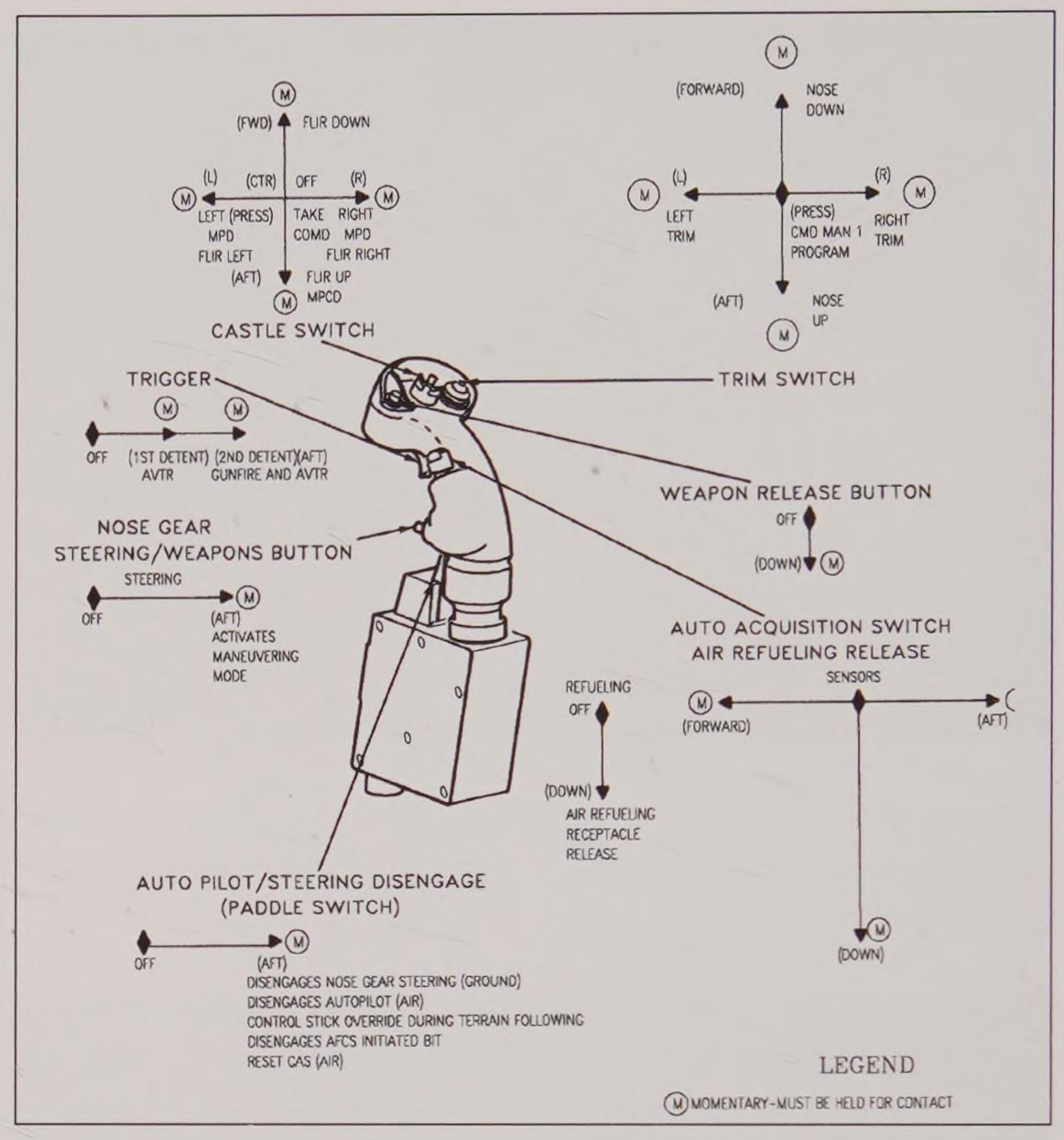

**ABOVE The F15E front stick grip is identical to that found in the MSIP Eagle.** *(USAF)*

**BELOW Another way to program the Strike Eagle's avionics and systems is via the upfront controller (UFC).** *(USAF)*



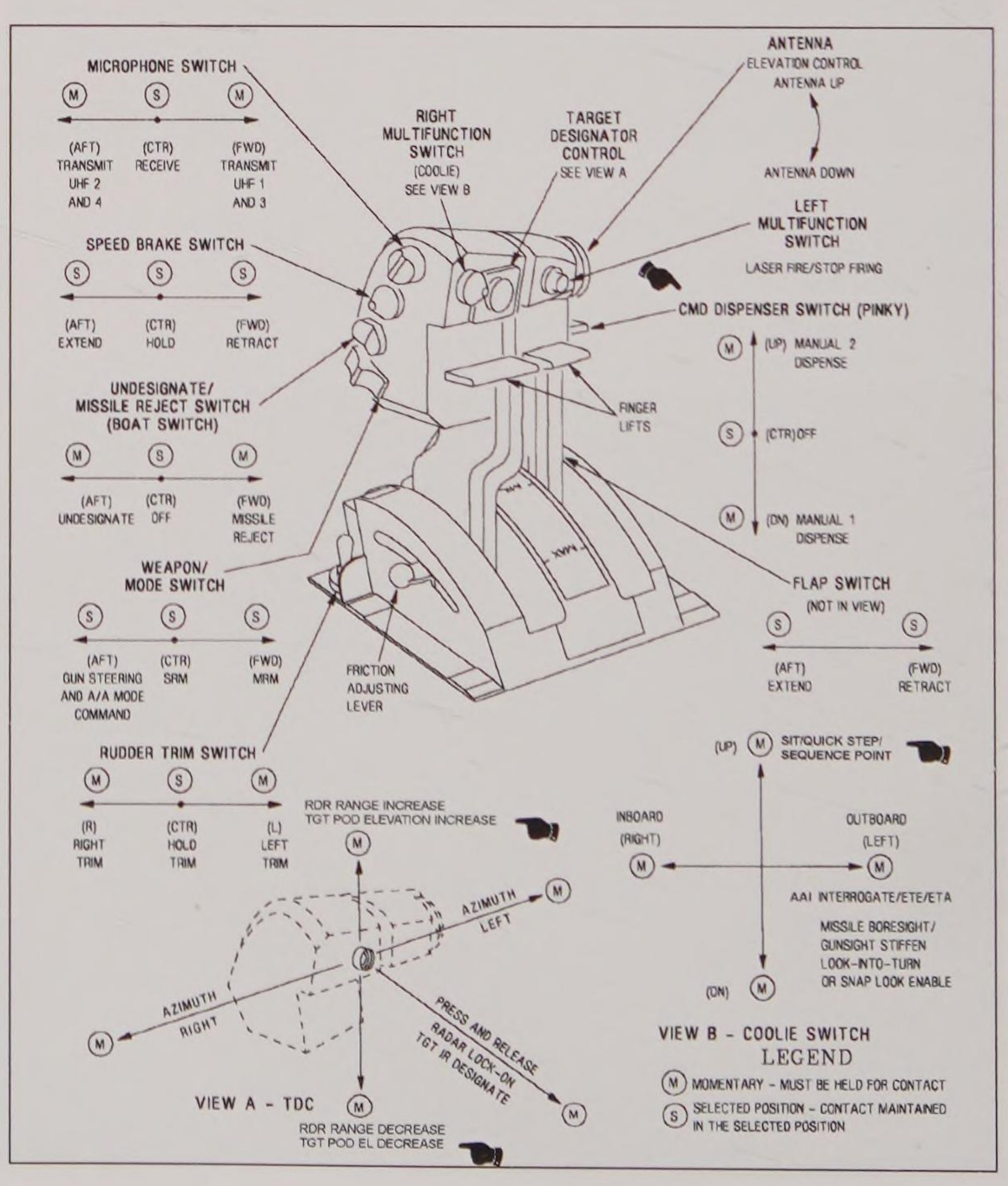

**BELOW The F-15E rear cockpit is roomy and well designed.**

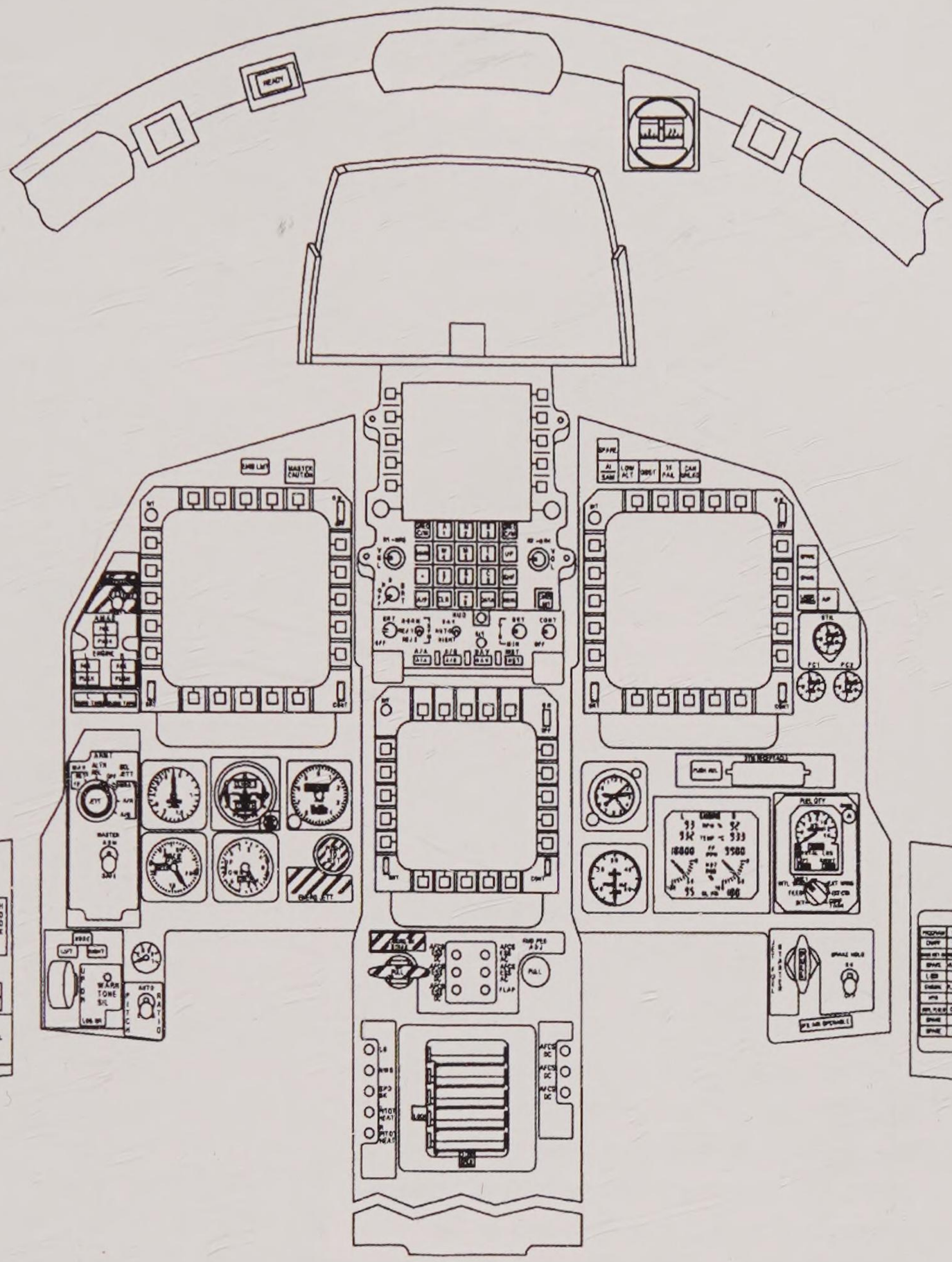
*(Steve Davies/FJPhotography.com)*



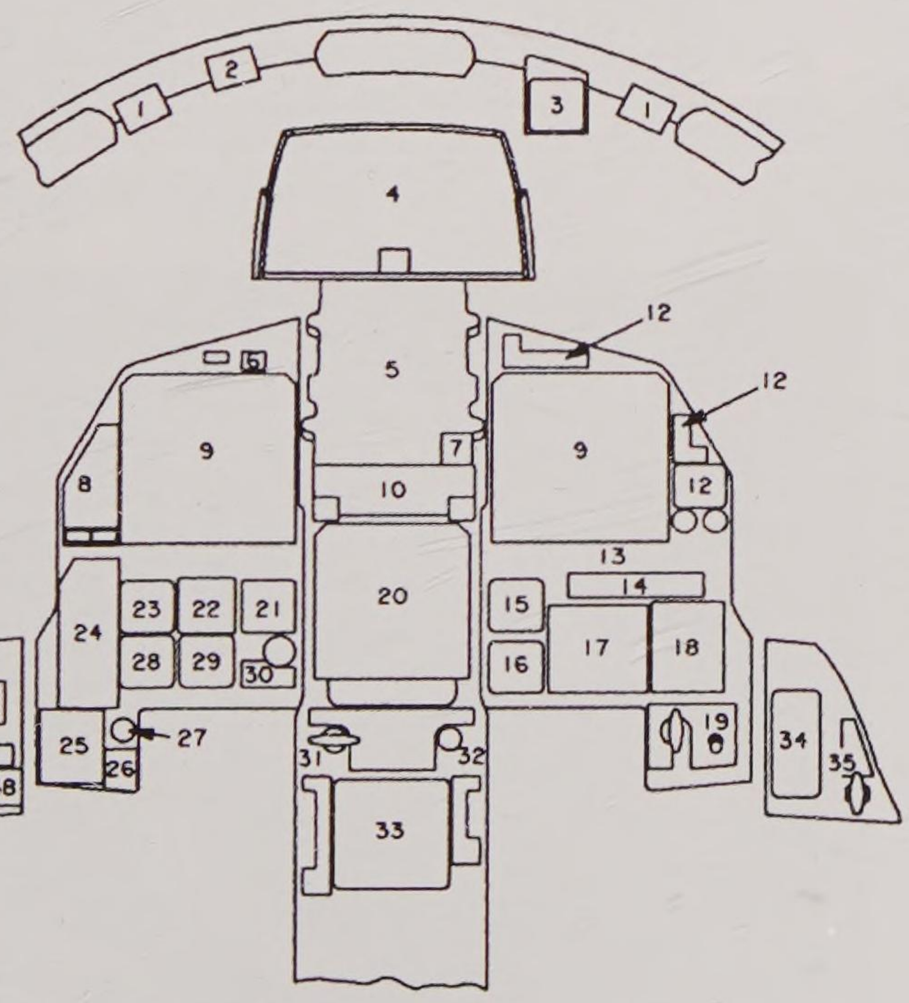

**ABOVE The stick grip's HOTAS functions explained in brief. HOTAS relies not only on button presses, but also the amount of time for which the button is held.** *(USAF)*

**BELOW Similarly, the throttle (front cockpit shown) gives the pilot access to weapons, navigation and aircraft systems by feel alone.** *(USAF)*



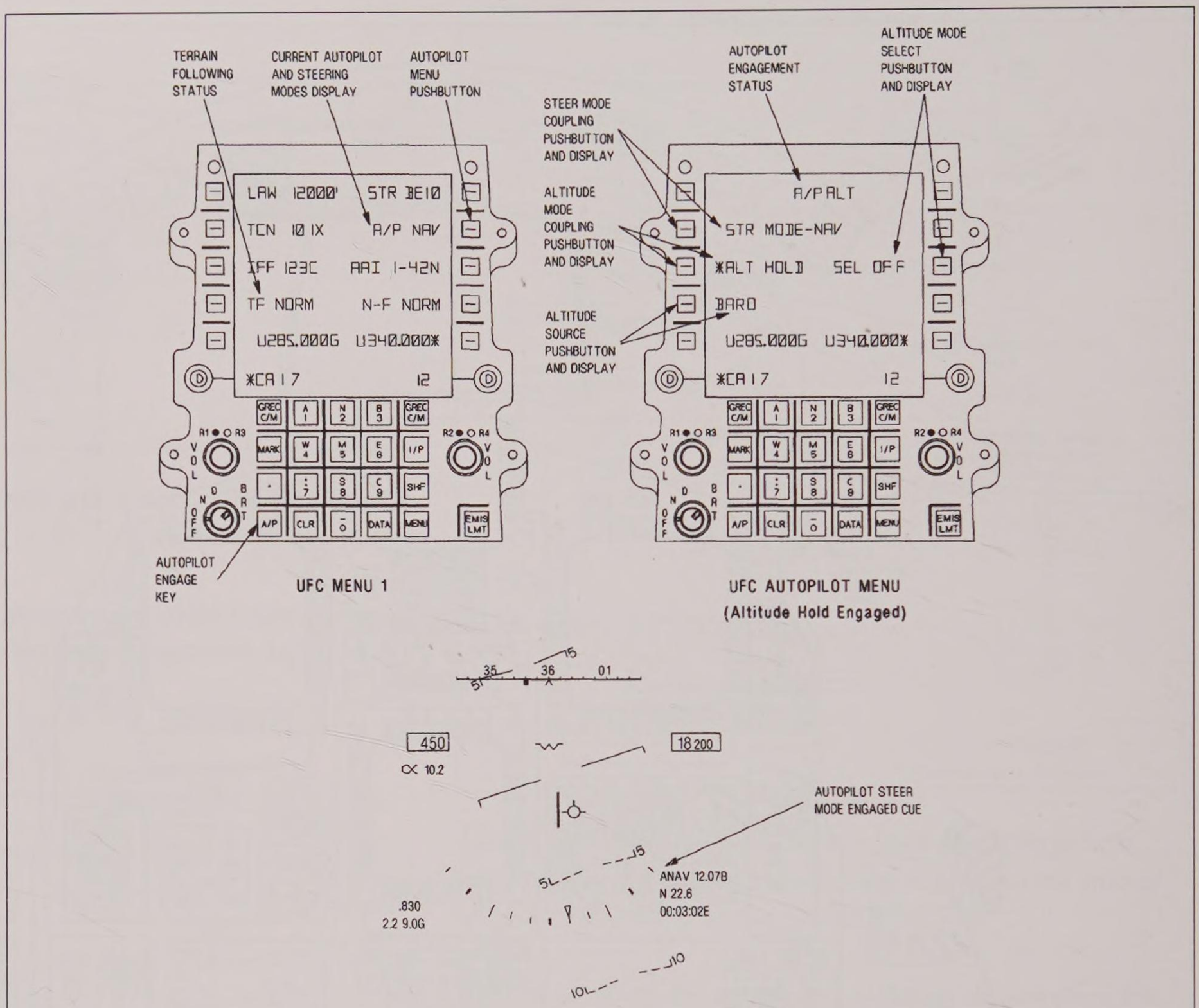


**Schematic of the Strike Eagle's front office.** *(USAF)*




1. LOCK/SHOOT LIGHTS
2. AIR REFUELING READY LIGHT
3. STANDBY MAGNETIC COMPASS
4. HEAD UP DISPLAY COMBINING GLASS
5. UPFRONT CONTROL PANEL
6. MASTER CAUTION LIGHT
7. EMISSION LIMIT SWITCH
8. FIRE WARNING/EXTINGUISHING PANEL
9. MULTI-PURPOSE DISPLAY
10. HEAD UP DISPLAY CONTROL PANEL
11. WARNING/CAUTION/ADVISORY LIGHTS
12. HYDRAULIC PRESSURE INDICATORS
13. BLANK
14. DATA TRANSFER MODULE RECEPTACLE
15. EIGHT DAY CLOCK
16. CABIN PRESSURE ALTIMETER
17. ENGINE MONITOR INDICATOR
18. FUEL QUANITY INDICATOR
19. JET FUEL STARTER CONTROL HANDLE/BRAKE HOLD SWITCH
20. MULTI-PURPOSE COLOR DISPLAY (MPCD)
21. ALTIMETER
22. STANDBY ATTITUDE INDICATOR
23. STANDBY AIRSPEED INDICATOR
24. ARMAMENT CONTROL PANEL
25. LANDING GEAR CONTROL HANDLE
26. PITCH RATIO SELECT SWITCH
27. PITCH RATIO INDICATOR
28. ANGLE OF ATTACK INDICATOR
29. VERTICAL VELOCITY INDICATOR
30. EMERGENCY JETTISON BUTTON
31. EMERGENCY BRAKE/STEERING CONTROL HANDLE
32. RUDDER PEDAL ADJUST RELEASE KNOB
33. COCKPIT COOLING AND PRESSURIZATION OUTLET
34. CAUTION LIGHTS PANEL
35. EMERGENCY VENT CONTROL HANDLE
36. ARRESTING HOOK CONTROL SWITCH
37. FLAP POSITION INDICATOR
38. RADIO CALL PANEL
39. EMERGENCY LANDING GEAR HANDLE

**RIGHT** **Autopilot displays, as they appear on the upfront controller and HUD.** *(USAF)*




**BELOW** **The stroke imagery in the HUD provides navigation, weapons and attack data to the pilot, depending on which master mode the aircraft is in. In navigation mode, these are the typical symbols that are displayed.** *(USAF)*

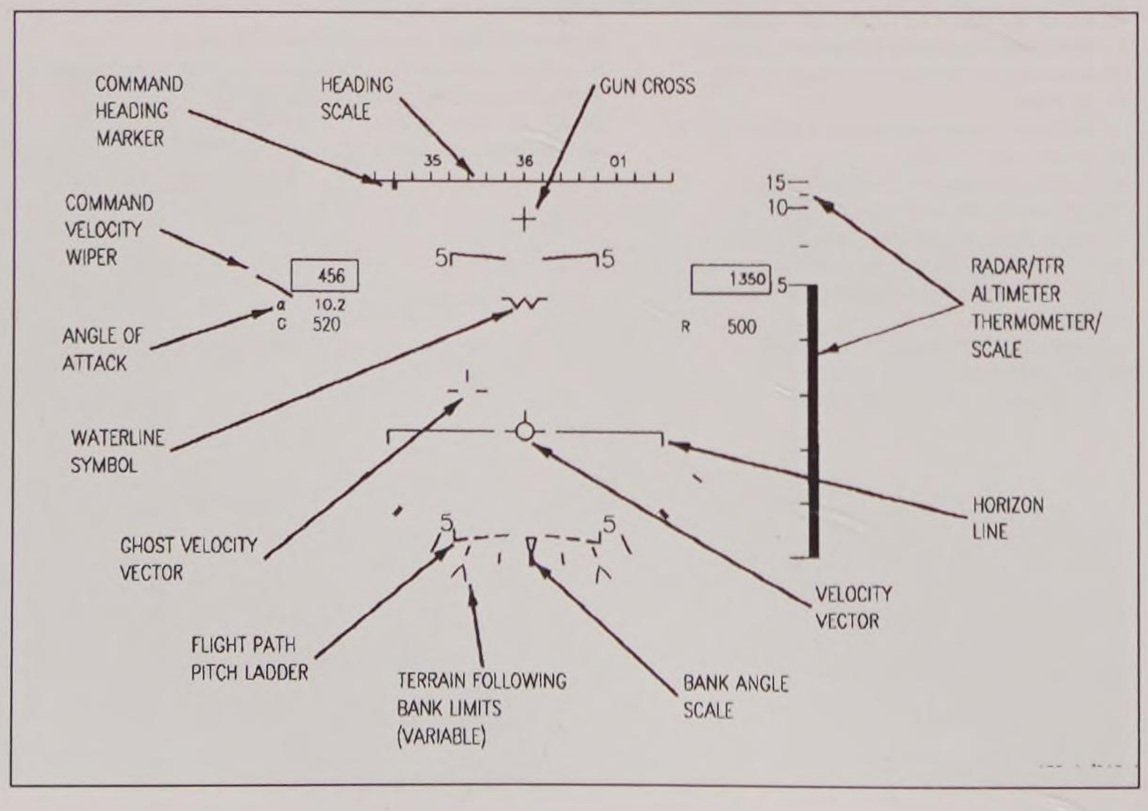
The rear cockpit control stick consists of a stick grip and force transducer and contains four controls: an autopilot/nose gear steering disengage switch (paddle switch), a weapon release button, a trim switch and an air-refuelling release button. The rear cockpit trigger is non-functional.

The rudder pedals operate conventionally and are adjustable. The rudder pedals are also used for the brakes and nose gear steering.

## Flap system

Each wing has a two-position trailing edge flap. The flaps are electrically controlled and hydraulically operated. When the flaps are down, they are protected from structural damage by the right air data processor (ADP). The right ADP automatically retracts the flaps at approximately 250kt. The flaps will automatically return to the down position at no less than 230kt, providing the flap control switch is in the down position.

**BELOW RIGHT** **Strike Eagle throttle quadrant (front cockpit), showing the HOTAS switches.** *(Steve Davies/ FJPhotography.com)*



## WEAPONS

### F-15E

One 20mm M61A-1 six-barrel gun, with 512 rounds, in starboard wing root. Wing pylons for AIM-9 Sidewinder, AIM-120 AMRAAM, and AIM-7 Sparrow, AGM-65 Maverick and AGM-130. A wide range of guided and unguided weapons including GBU-31, -38 and -54 JDAM, GBU-39 SDB, GBU-10, -12, -15, -24, -28; EGBU-15 and -24; Mk 82, Mk 84, CBU-87, -89, -97; B57 and B61 nuclear weapons. For AGM-130 and E/GBU-15 missions an AXQ-14 data link pod is also carried. Three 600 US gallon external fuel tanks. MXU-648 travel pod.

**ABOVE The GBU-28 bunker-buster bomb weighs 5,000lb and is carried only on the Strike Eagle's centreline station.** *(Steve Davies/FJPhotography.com)*

**RIGHT The JDAM (joint direct attack munition) series of weapons came as a consequence of bad weather adversely affecting US performance in the Balkans over the course of the 1990s. Here, an F-15E releases five 2,000lb GBU-31s. GPS-guided, they can be dropped through the weather with incredible precision.** *(USAF)*

**BELOW Two laser-guided bombs (with seeker heads not attached) and an air-inflatable retard 'dumb bomb'. From right to left: GBU-10, GBU-24 and Mk 82 AIR general purpose bomb. At the rear are two Mk 84 low drag general purpose bombs.** *(Steve Davies/FJPhotography.com)*

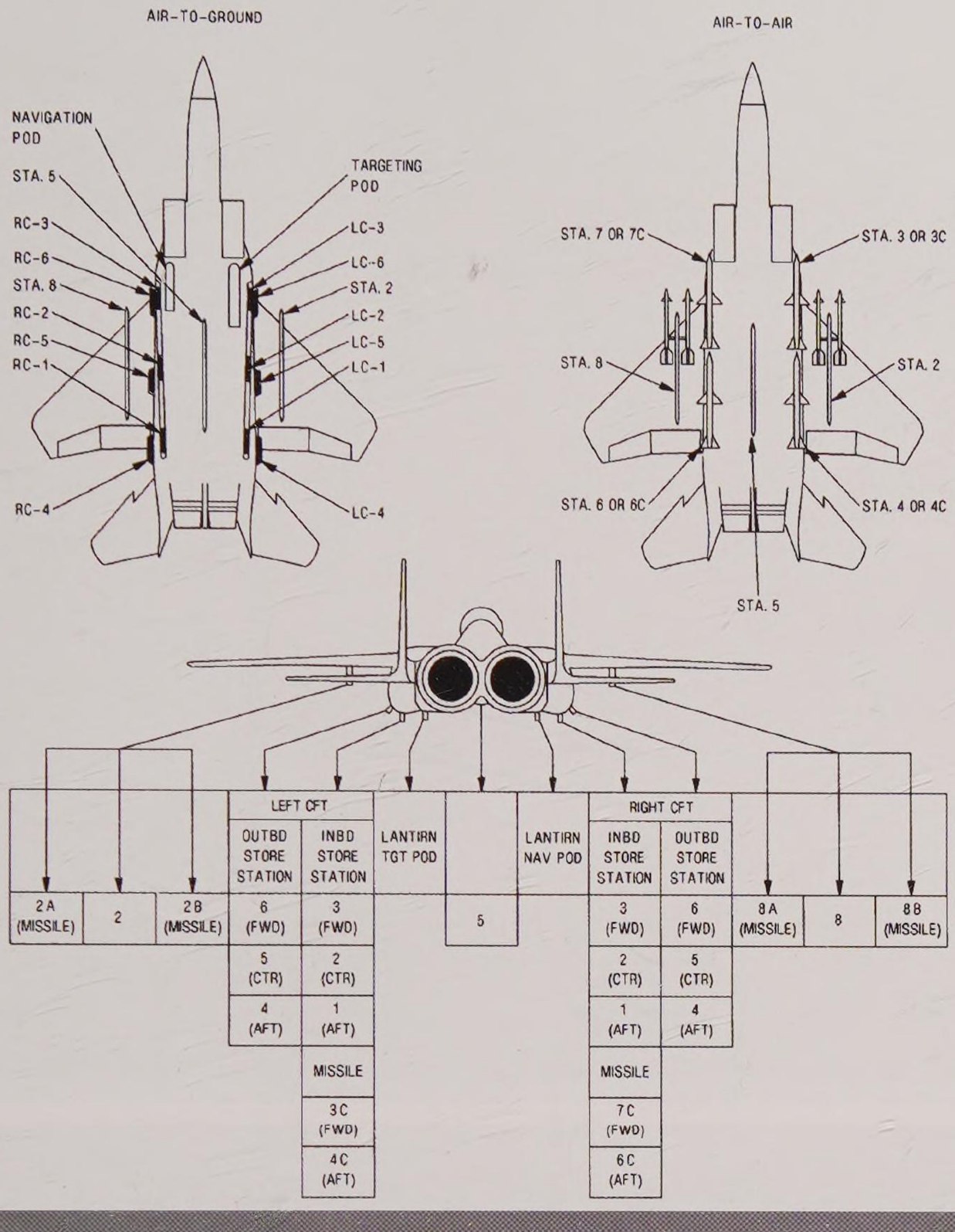
**RIGHT A pair of CBU-97s sit ready for loading. This weapon contains 'skeets' that search out the heat sources of tanks and armoured vehicles to strike them en masse on the battlefield.** *(Steve Davies/FJPhotography.com)*

**ABOVE** The seeker element is gimballed to allow it to look straight into the relative airflow both prior to and post release. *(Steve Davies/FJPhotography.com)*

**ABOVE** The GBU-15's rear control fins feature trailing edge control surfaces that move to control pitch and roll attitude during flight. *(Steve Davies/FJPhotography.com)*

**LEFT** An F-15E drops four GBU-12 laser-guided bombs. At 500lb, the GBU-12 is an ideal choice for employment against targets in urban areas. *(USAF)*

**BELOW** A trolley of AIM-9M and AIM-120B AMRAAMs. The AMRAAM has ensured that the Eagle has remained a world-class air superiority fighter. *(Steve Davies/FJPhotography.com)*



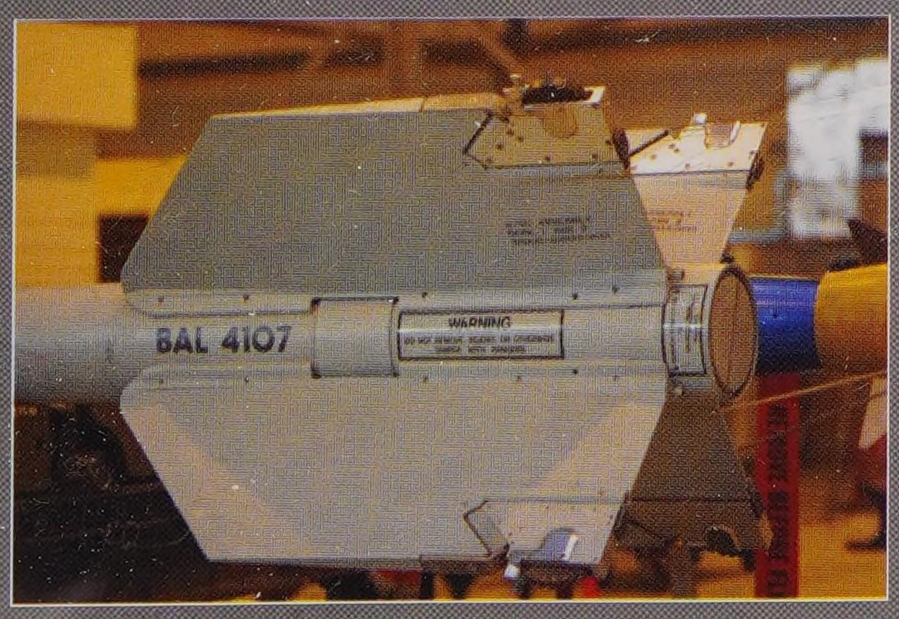

**LEFT The nomenclature for the F-15E's stores loading stations and pylons.** *(USAF)*

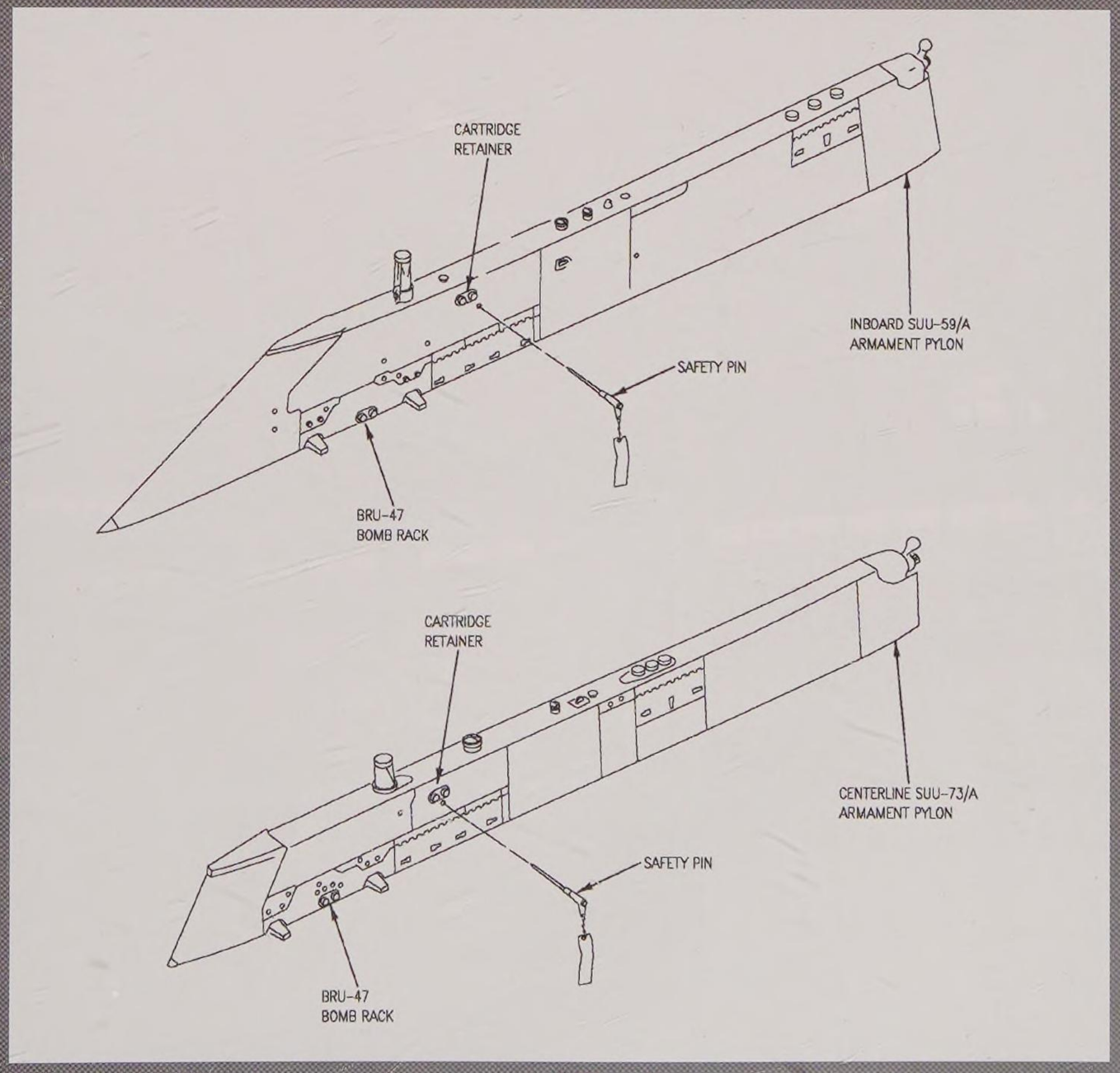
**BELOW Schematic for the two main types of armament pylons installed on the F-15.** *(USAF)*

## F-15A/B/C/D

One 20mm M61A-1 six-barrel gun, with 940 rounds, in starboard wing root. Wing pylons for AIM-9 Sidewinder, AIM-120 AMRAAM, and AIM-7 Sparrow. Three 600 US gallon external fuel tanks. MXU-648 travel pod.

**BELOW The rear control fins of the AIM-9 feature little 'rollerons' that give the missile stability in flight.** *(Steve Davies/FJPhotography.com)*



**RIGHT** **Horizontal stabilators (stabs) sit ready to be mated to the empenage of F-15E E228 at Boeing's St Louis, Missouri, production plant.** *(Steve Davies/ FJPhotography.com)*

**BELOW** **Meanwhile, the wings sit on dollies awaiting mating with the fuselage.** *(Steve Davies/ FJPhotography.com)*

**LEFT** **The green and yellow coatings are corrosion resistant and act in the same way as zinc chromate to protect the aluminium and other manufacturing materials.** *(Steve Davies/ FJPhotography.com)*

## Hydromechanical flight control system

The hydromechanical flight control system uses mechanical linkages and hydraulic actuators to position the flight control surfaces.

## Longitudinal control

Longitudinal stick motion positions the stabilators symmetrically to provide pitch control. The ratio of symmetrical stabilator motion to longitudinal stick motion (pitch ratio) is automatically adjusted for altitude and speed. This provides the same pitch response (constant g) for a given stick deflection regardless of airspeed. The ratio is high (greatest stabilator authority) at low speeds, and low at high speeds at low altitude. If hydraulic pressure is lost, the pitch ratio will drive to an intermediate position and lock. If the mechanical linkage becomes jammed, mechanical longitudinal control is lost; however, the CAS can provide enough stabilator control for moderate flight manoeuvres and landing.

The longitudinal control system includes a manual trim and an automatic trim. The manual trim is controlled by the trim button on the stick. The manual trim actuator changes the neutral position of the longitudinal feel spring cartridge to reposition neutral stick position and thus neutral stabilator position.

When airborne, the flight control system automatically trims the stabilator without affecting stick position to compensate for changes in trim caused by such things as changing speed, operating flaps or speed brake, or store separations. On the ground, the PTC (pitch trim controller) slowly trims the stabilator to either the extreme forward or aft limit of its authority as the stick is positioned forward or aft of the neutral stick position. This stick positioning can take place by manual stick inputs or by manual trim.

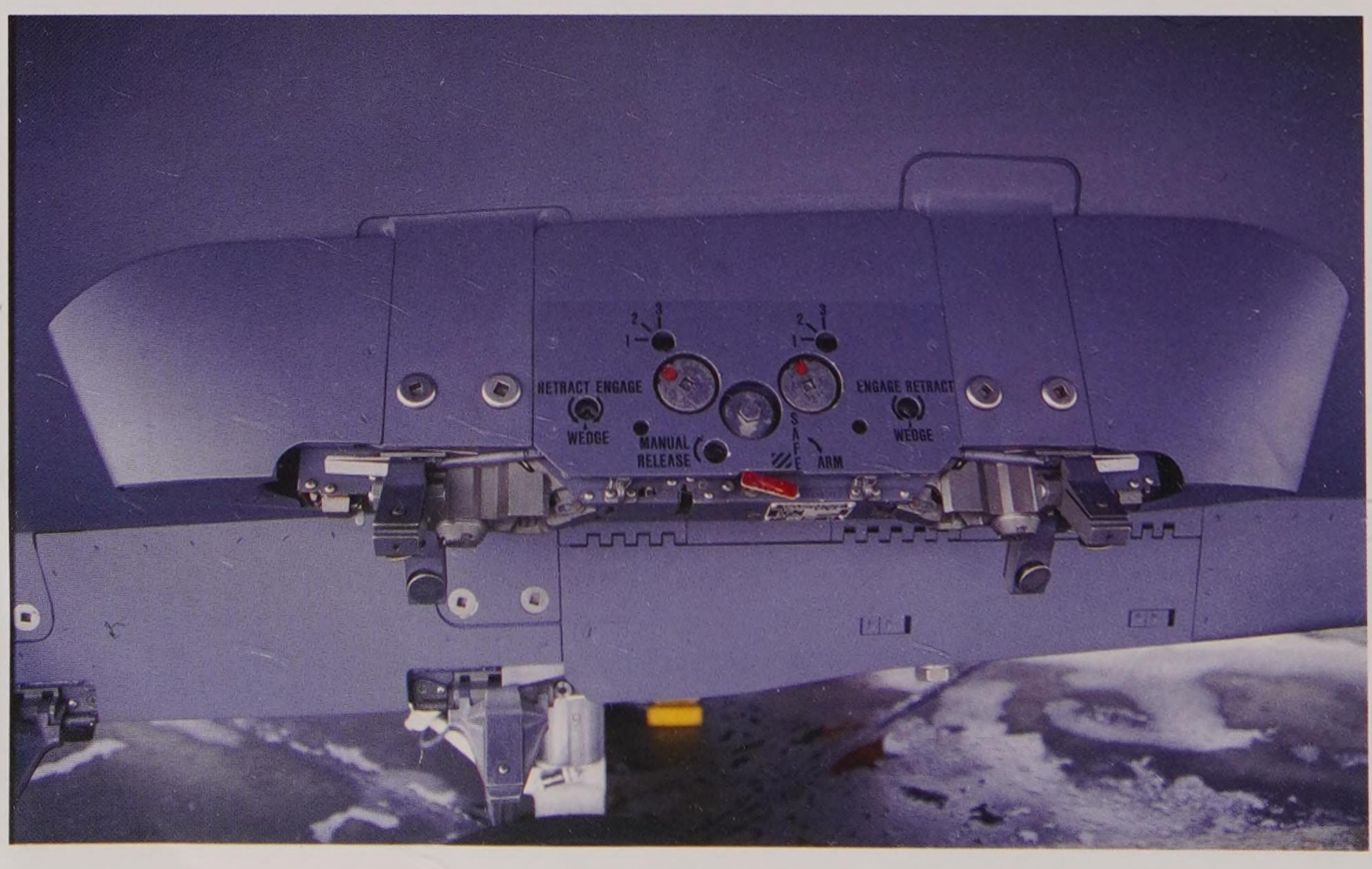
The pitch ratio indicator on the main instrument panel shows the ratio of symmetrical stabilator motion to longitudinal stick motion. For a given stick motion, the stabilators move most at a pitch ratio of 1.0 and least at zero. The ratio should be 1.0 at slow speeds and near zero at Mach 0.9 near sea level. Pitch ratio

**RIGHT Standing in the sub-zero conditions of winter in Idaho, a CFT sits on a dolly at Mountain Home AFB.** *(Steve Davies/ FJPhotography.com)*

will then increase as speed increases above Mach 1.0. The indicator will show 0.3 to 0.5 if the pitch ratio switch is placed in 'EMERG' or hydraulic pressure is lost.

The 'PITCH RATIO' caution comes on if hydraulic pressure is lost to the control stick boost/pitch compensator (CSBPC), the pitch ratio switch is in the 'EMERG' position, or the pitch ratio versus airspeed is incorrect below 20,000ft. However, with the gear down and airspeed above 220kt the 'PITCH RATIO' caution may come on until the pitch ratio drives to above 0.9. This condition is normal and should be disregarded.

**ABOVE With the CFT removed, some of the Strike Eagle's fuselage panels must be replaced.** *(Steve Davies/ FJPhotography.com)*




**RIGHT Bomb release units (BRUs) are installed on each CFT in two rows of three.** *(Steve Davies/ FJPhotography.com)*

## Lateral control

Lateral stick motion positions the ailerons, rudders and stabilators to provide roll control. The ratio of aileron/differential stabilator deflection to lateral stick motion (roll ratio) is adjusted automatically for different airspeeds, longitudinal stick position and gear position. Aileron and differential stabilator deflection are washed out to prevent adverse yaw when longitudinal stick deflection is combined with lateral stick deflection.

At subsonic speeds, the roll ratio is high; at supersonic speeds the roll ratio is reduced. Additional roll ratio reductions also occur as the stick is moved forward or aft.

With the landing gear down, full aileron/differential stabilator is available at any longitudinal stick position. If UTL A and PC2A hydraulic pressures are lost or the roll ratio switch is in 'EMERG', the roll ratio drives to mid-range and locks. A spin recovery aid provides full lateral control authority, regardless of longitudinal stick position, when the yaw rate exceeds 41.5°/second and remains greater than 30° per second for five seconds. If the yaw rate exceeds 57° per second, spin recovery aid is available immediately. The spin recovery aid is discontinued (normal control authority) when the yaw rate drops below 30° per second.

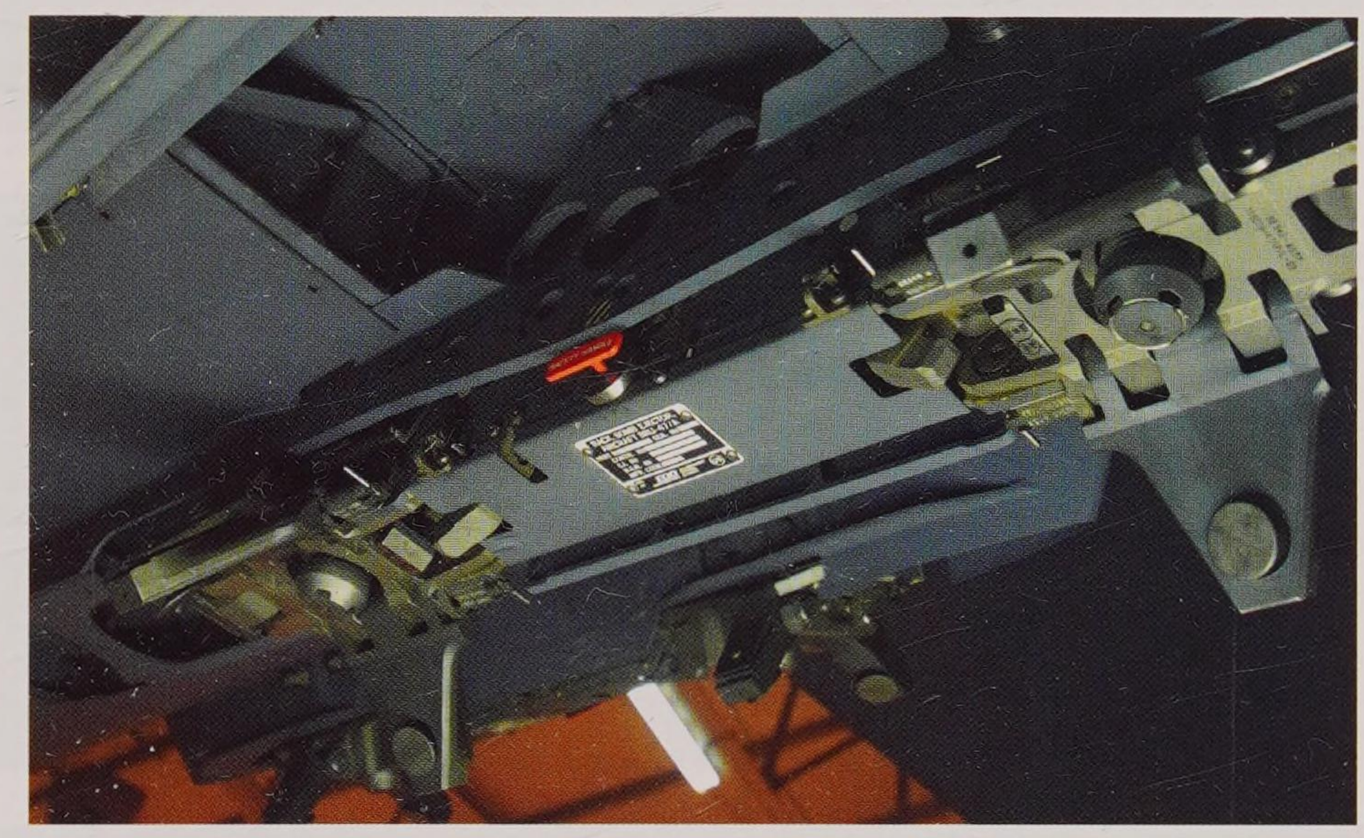
The mechanical ARI adjusts the control system such that lateral stick motion results in varying rudder deflection dependent on longitudinal stick position.

With the control stick aft of neutral, lateral stick motion causes rudder deflection in the same direction as stick motion. With the control stick forward of neutral, lateral stick motion causes rudder deflection in the opposite direction of the stick motion. With the flaps down, the point where longitudinal stick position causes opposite rudder motion with a lateral input is shifted forward of neutral. This position shift causes the amount of rudder deflection for lateral input to increase with aft stick movement.

The ARI is disengaged at supersonic speeds and on landing. If the anti-skid system detects a malfunction, or the landing gear circuit breaker is 'OUT', the ARI may remain engaged at wheel spin-up, adversely affecting crosswind

**LEFT The left CFTs on PW-220 jets have small, spring-loaded air scoops to provide avionics cooling.** *(Steve Davies/ FJPhotography.com)*

**BELOW The BRUs were designed with speedy loading and ease of use in mind. They will automatically align the weapon during loading.** *(Steve Davies/ FJPhotography.com)*

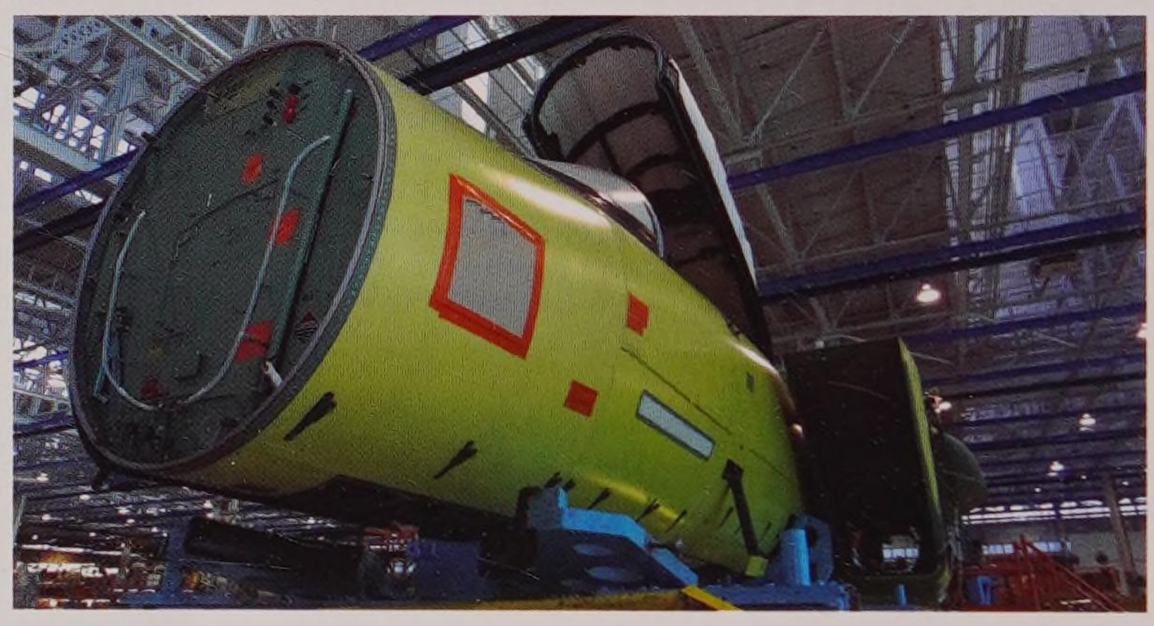


**LEFT The ailerons (furthest from camera) and flaps (shown retracted) are the only parts of the Eagle's wings that move. Unlike most contemporary fighters, the F-15 has no leading edge control surfaces such as slats.** *(Steve Davies/ FJPhotography.com)*

**ABOVE** **With the forward fuselage and vertical stabilators mated to the main section, the Strike Eagle takes shape.** *(Steve Davies/FJPhotography.com)*

**RIGHT** **The radar will be installed in the last stage of production, just prior to test and acceptance flights.** *(Steve Davies/FJPhotography.com)*

**BELOW** **At the attachment point, plumbing for the fuel tanks can be seen.** *(Steve Davies/FJPhotography.com)*

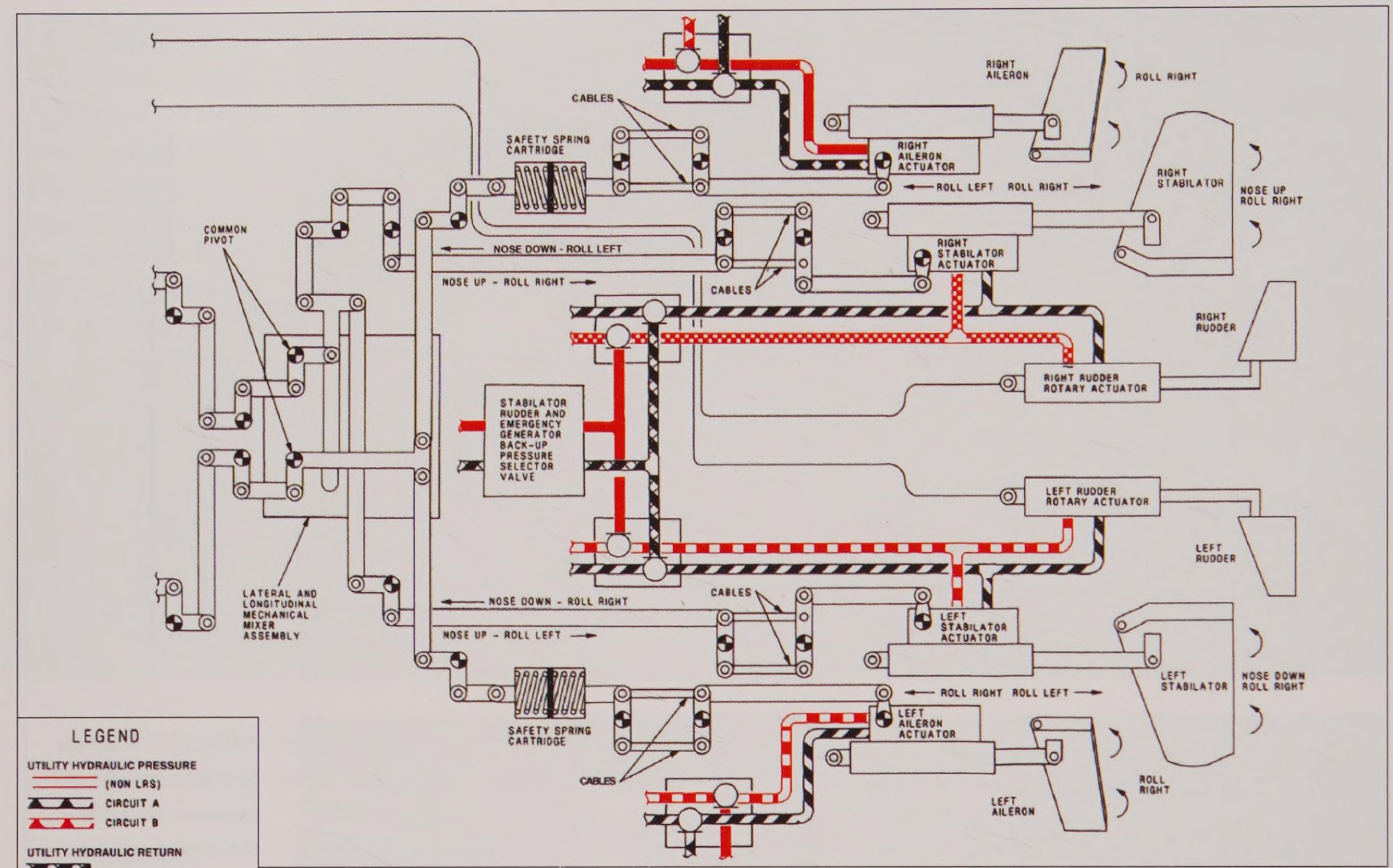


**LEFT A man (in orange) appears from within the common engine bay at roughly the point where the right PW-229 compressor stage will be once the engines are installed.** *(Steve Davies/ FJPhotography.com)*

**FAR LEFT The rear fuselage empenage receives no paint – the heat from the engines is so great that it would simply peel off.** *(Steve Davies/ FJPhotography.com)*

**LEFT The stabs are made from a composite honeycomb material covered by a skin that has been known to delaminate and peel back during flight, resulting in the loss of at least one Eagle.** *(Steve Davies/ FJPhotography.com)*

**LEFT There are four main attachment points that mate the wing to the fuselage.** *(Steve Davies/ FJPhotography.com)*




landing characteristics. Turning the anti-skid switch to 'OFF' or 'PULSER' will insure ARI disengagement. If UTL A and PC2A hydraulic pressures are lost or either the pitch or roll ratio switch is in 'EMERG', the ARI is inoperative. If the mechanical system is inoperative, the differential stabilators (through roll CAS) will provide lateral control for moderate manoeuvres including landing.

## Lateral trim/feel system

The aircraft is trimmed laterally using the trim button on the stick. The trim actuator changes the neutral position of the lateral feel spring cartridge to reposition neutral stick position and thus neutral aileron/differential stabilator position.

## Yaw control

Rudder pedal motion positions the rudders to provide yaw control. If the rudder linkage jams, safety spring cartridges allow the rudder pedals to move to permit nose-wheel steering. The rudders are still actuated through the CAS (CAS alone provides only about half rudder deflection). If the nose-gear steering jams, similar devices permit rudder operations.

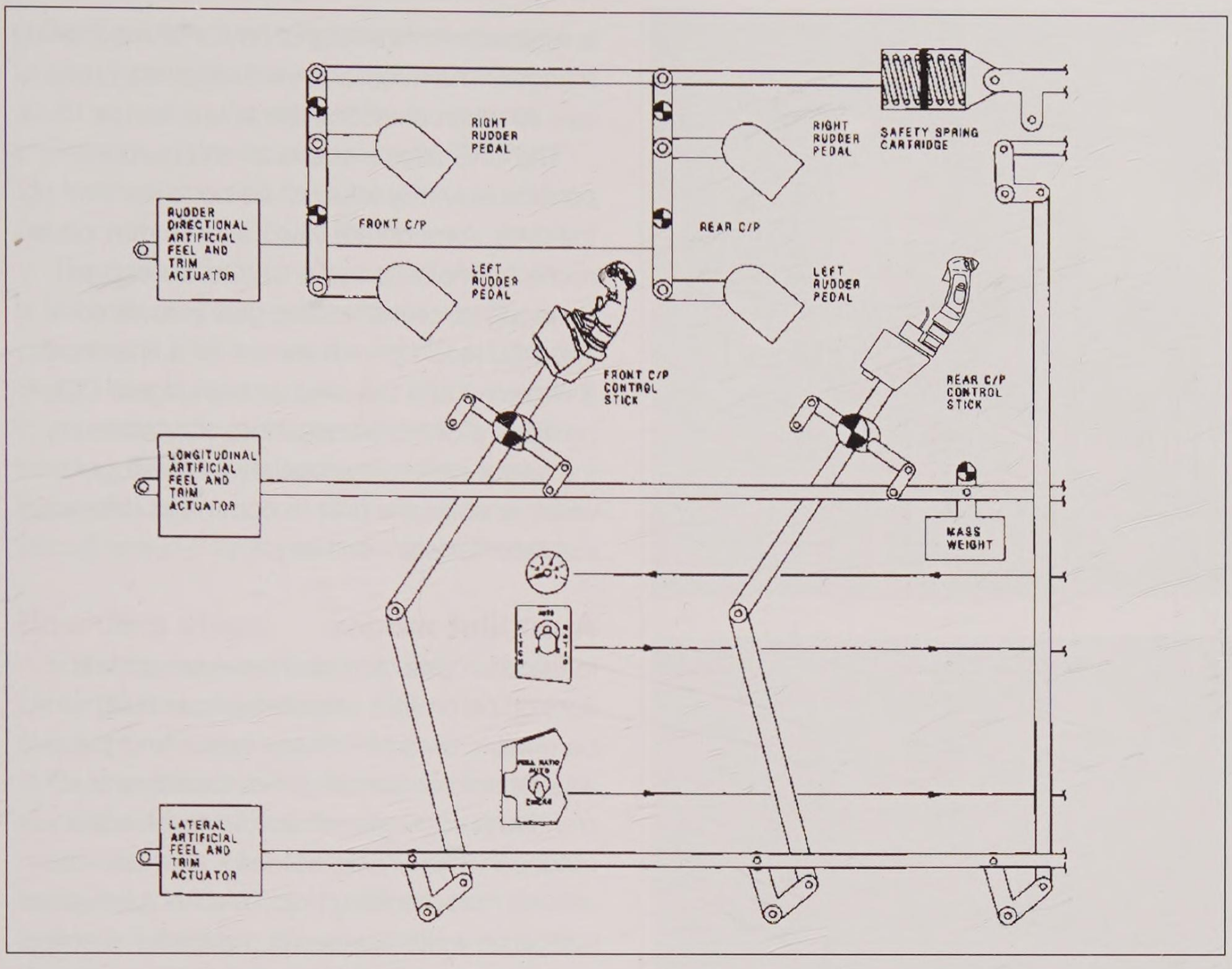
## Automatic flight control system (AFCS)

The AFCS provides roll, pitch and yaw control augmentation, autopilot modes in roll and pitch axes, terrain-following in the pitch axis and a direct electronic link (DEL) mode in a spin. DEL provides differential stabilator for spin recovery.

## Control augmentation system (CAS)

Superimposed on the hydromechanical flight control system is a three-channel, three-axis control augmentation system. The CAS responds to electrical signals generated by forces applied to the control stick and to rudder pedal position. These signals modify the control surface deflections commanded by the hydromechanical flight control system to provide the desired flying qualities.

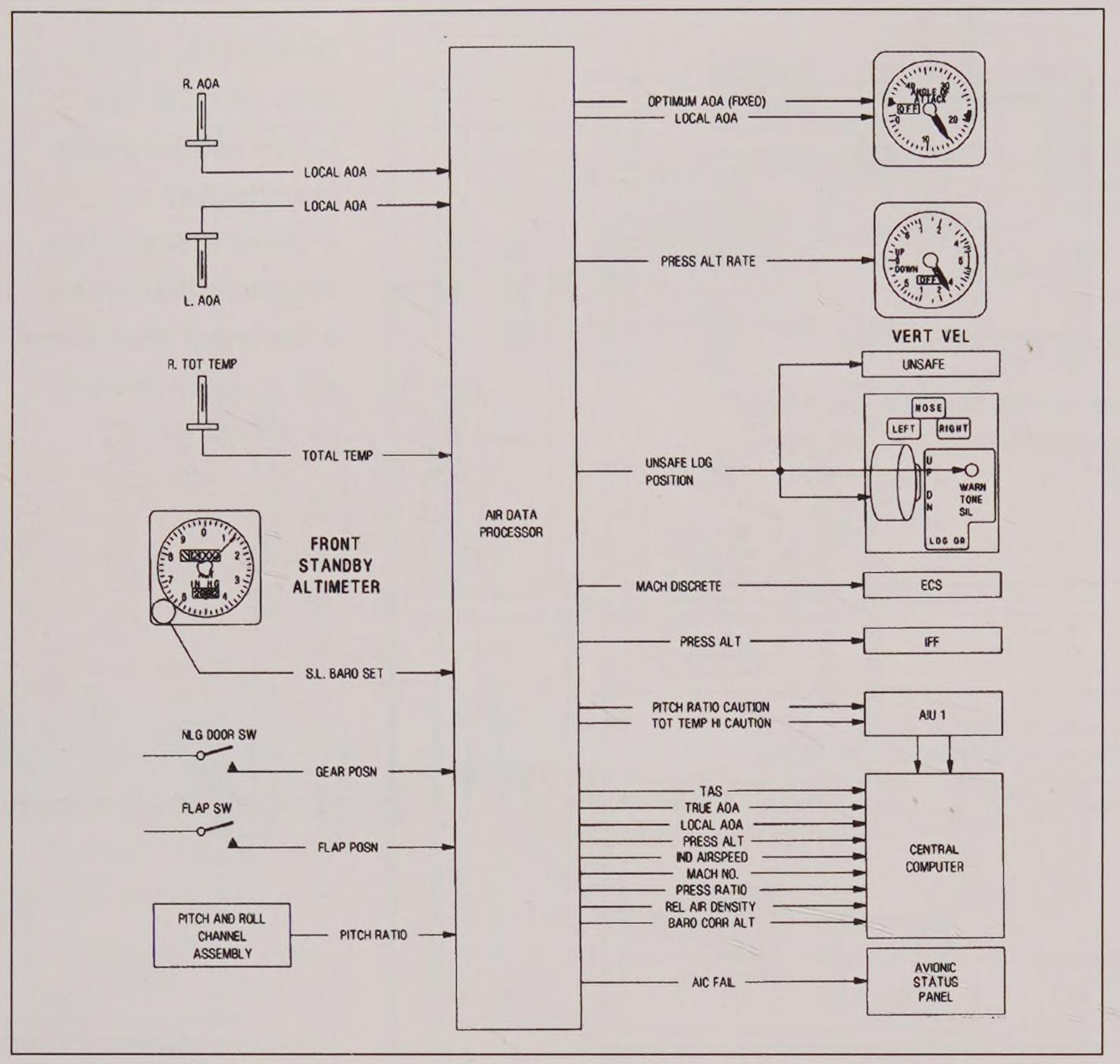
The CAS also provides damping on all three axes. At high AOA, CAS provides improved lateral directional stability and improved coordination. Since CAS inputs are applied directly to the actuator and the stick inputs are due to force and require no control stick motion, with the CAS on, limited aircraft control

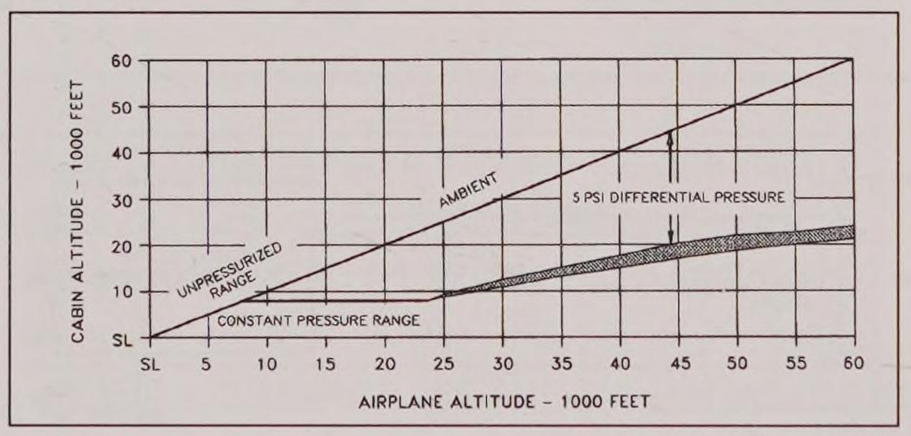






**OPPOSITE, LEFT AND BELOW** The F-15's control sticks are attached to artificial feel and trim actuators that create a 'constant stick force per g', regardless of air speed. *(USAF)*

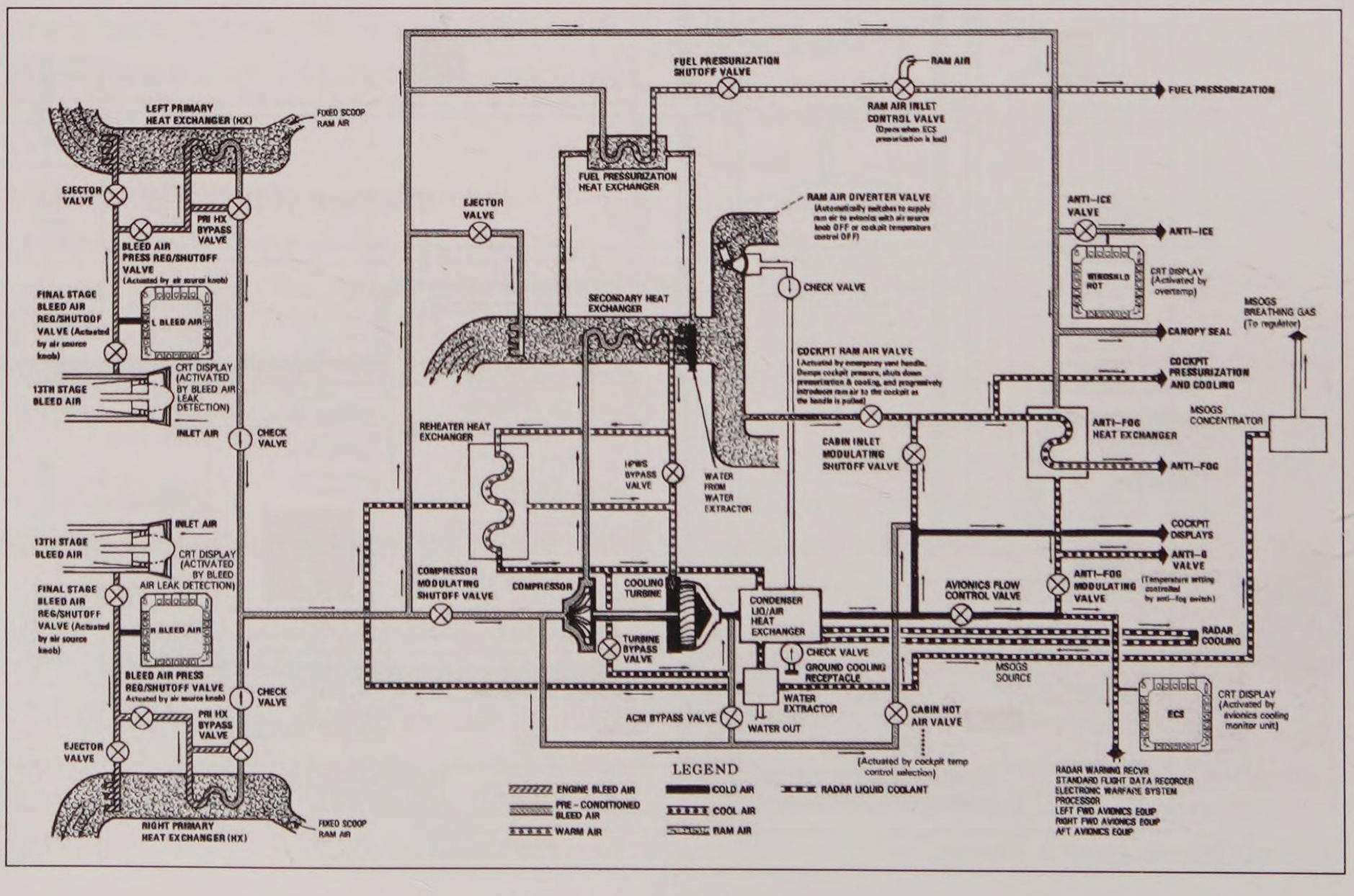



**ABOVE The air data system takes inputs from a range of other subsystems and sensors in order to provide flight information to the pilot.** *(USAF)*

**CENTRE The Eagle and Strike Eagle cockpits are pressurised to a fixed schedule.** *(USAF)*

**RIGHT The ECS (environmental control system) takes engine bypass air and uses it to cool or heat aircraft systems, as required.** *(USAF)*




is retained with the loss of any or all mechanical linkages. The three-channel design turns any axis off when a second like failure occurs.

The CAS affects stabilator and rudder position only; the ailerons are not controlled by the CAS. A moderate yaw transient may occur and is normal when yaw CAS is disengaged, re-engaged, or the landing gear is lowered. The DEL mode is activated when a spin mode is detected and the CAS is disengaged. DEL provides a direct electrical interconnect from the lateral stick to the stabilator actuators, which enables the pilot to command differential stabilator for spin recovery.

## Autopilot modes

In the pitch axis, autopilot provides attitude control, barometric or radar altitude hold, barometric or radar altitude select, and the altitude hold or altitude select functions of blended autopilot/terrain-following (blended mode). In the roll axis, autopilot provides attitude hold, heading hold, TACAN (tactical air navigation system) steering, navigation steering or ground track steering.

## Audio warning system

The audio warning system is made up of both audio tones and voice warnings. The weapons lock-on tone, tactical electronic warfare suite

(TEWS) caution and launch tones, instrument landing system (ILS) audio, and TACAN audio are volume-controlled by the remote intercommunications control panel (RICP) for the front cockpit and the intercommunications set control panel (ICSCP) for the rear cockpit.

The overload warning system (OWS) tone is generated by the multi-purpose display processor (MPDP) when the aircraft approaches design limit structural overload. When overload is exceeded, the tone is replaced with a voice warning. The unsafe landing warning tone is generated as a function of landing gear position, aircraft altitude, airspeed and rate of descent.

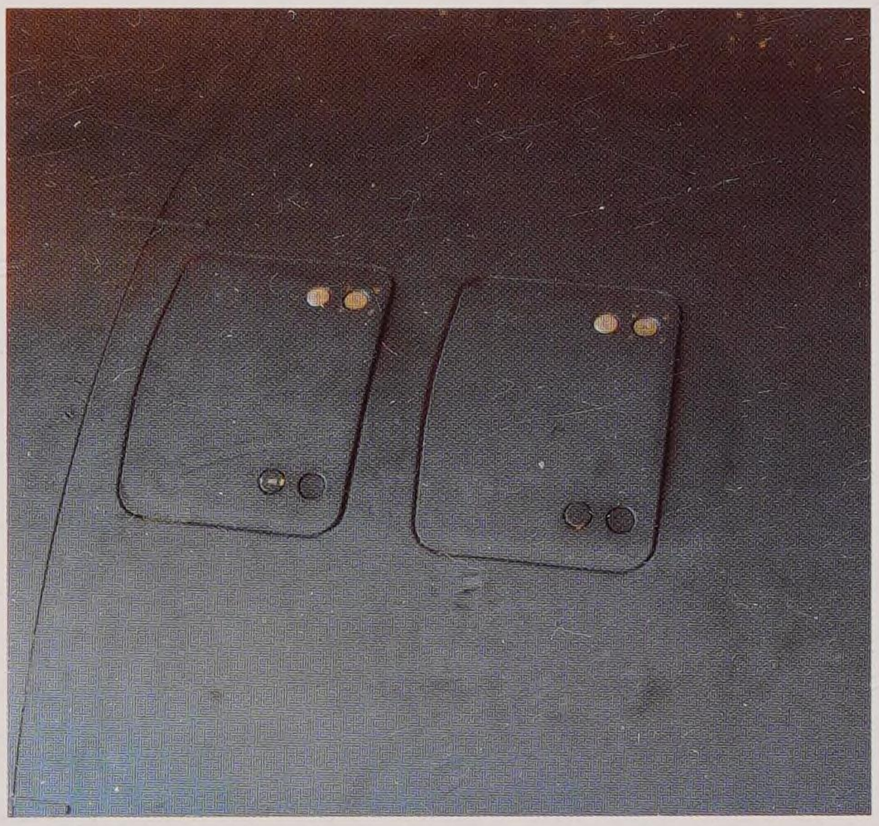
## Boarding steps

A boarding steps position indicator on the left canted bulkhead will display 'UP' when the steps are retracted and 'DOWN' when the steps are extended. The retractable boarding steps are released by pressing one of two release buttons. One release button is located inside the top kick-in step and another release button is located on the retractable step door. Pressing either button allows the steps to freefall to the down position.

## Canopy system

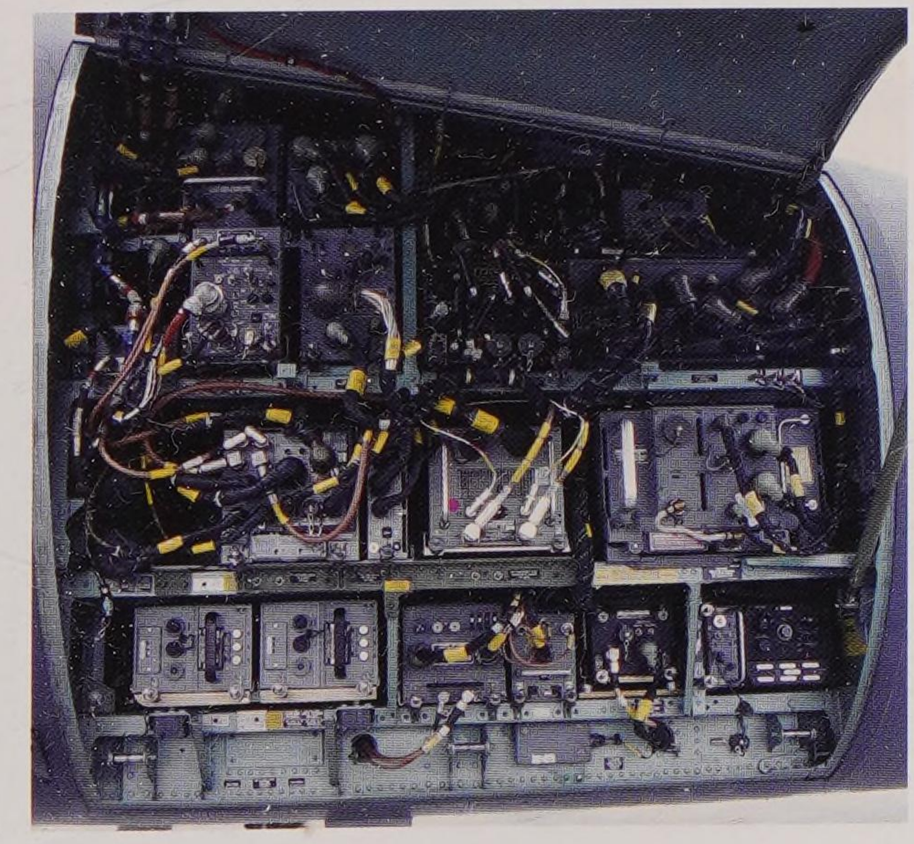
The cockpit area is enclosed by a clamshell-type canopy and an impact-resistant

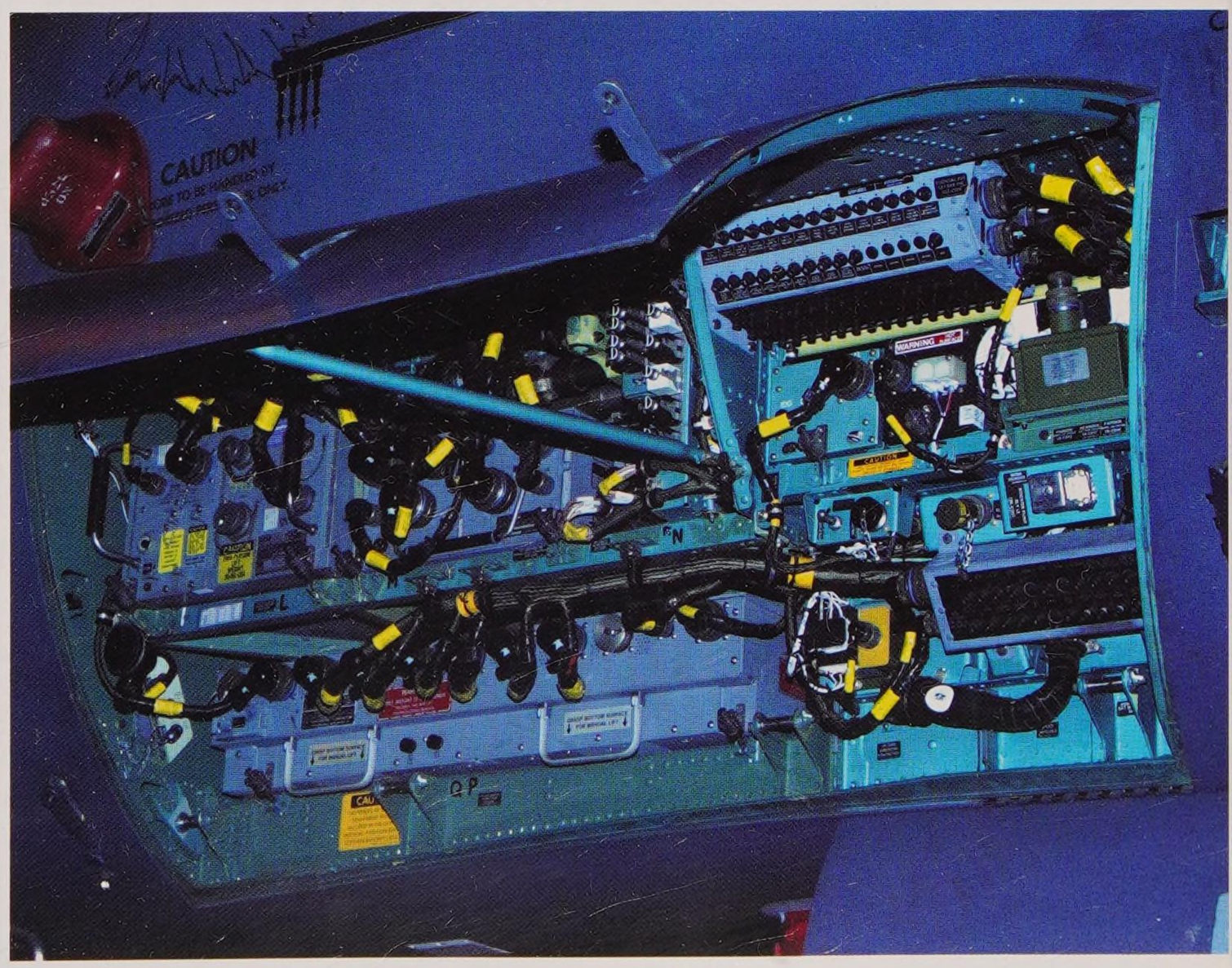
**ABOVE A look through the fuselage with engines removed.** *(USAF)*

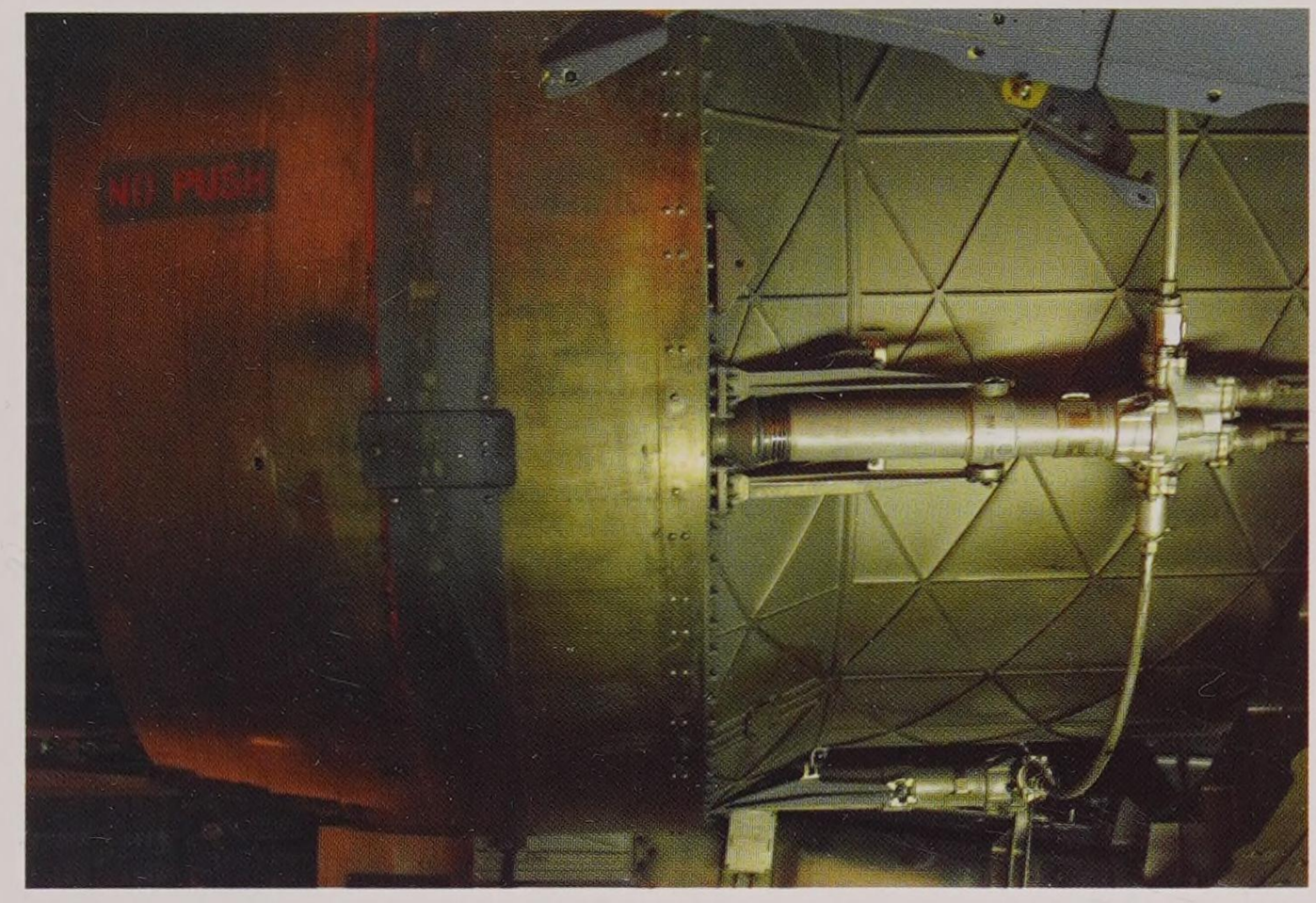


**LEFT Beneath these covers lie the connections that bolt the F100 engines into the Eagle. Located on the upper fuselage, each engine is connected by only two sets of the attachment points.** *(Steve Davies/FJPhotography.com)*

**BELOW AND RIGHT Avionics bays house multiple 'black boxes', more formally known as line replaceable units. When one breaks, the crew chief or specialist can simply remove it and replace it with another.** *(Steve Davies/FJPhotography.com)*








**ABOVE The back end of the PW-229 engine. The crosshatch mould lines differentiate it from the PW-220 or PW-100.** *(Steve Davies/ FJPhotography.com)*

windshield. The main components of the canopy system are a hydraulic actuator which provides manual and powered operation of the canopy, a locking mechanism, and a pyrotechnic canopy remover for emergency jettison. Latches on the canopy frame and along the lower edge of the canopy engage fittings on the cockpit sill structure to lock the canopy to the fuselage. An inflatable seal, installed around the edge of the canopy frame, retains cockpit pressure when the canopy is locked.

For normal canopy operation, an internal canopy control handle is provided on the right side of the cockpit under the canopy sill in both cockpits. For operation of the canopy from outside the aircraft, an external canopy control handle is located on the left side of the aircraft below the canopy. The external canopy control handle duplicates operation of the internal canopy control handle.

The canopy may not fully close with hydraulic pressure if ambient temperature is below 32°F. In this case, and after attempting to close the canopy mechanically, the pilot may assist the canopy in fully closing. With canopy down on the sills, and the internal control handle set to 'DOWN', grab hold of the two handles on the forward arch of the canopy and shove the canopy forward. Once the canopy moves fully forward, the control handle may be moved to the 'LOCKED' position after waiting ten seconds.

An accumulator provides hydraulic power for powered operation of the canopy (2½ to 3 cycles) when utility hydraulic pressure is not on the aircraft. Accumulator may not fully close the canopy if the ambient temperature is outside the 30°F to 110°F range. A hand pump is installed in the nose wheel-well to operate the canopy with hydraulic pressure off the aircraft and accumulator hydraulic pressure depleted.

The canopy can be operated without accumulator pressure by moving the external canopy control handle or one of the internal canopy handles to the 'UP' or 'DN' position, as desired, and then operating the hand pump in the nose wheel-well.

For ground egress with accumulator hydraulic pressure depleted, the canopy can be opened by placing the internal canopy control handle to 'UP' and then pushing up on the canopy. A nitrogen charge in the canopy actuator aids in opening the canopy manually.

The internal and external canopy control handles are used to lock the canopy mechanically by placing the handle to 'LOCKED' from the 'DN' position, once the canopy is fully closed.

For canopy jettison, a pyrotechnic canopy remover operates independently of the normal canopy system. The canopy remover, behind the front seat, is designed to safely jettison the canopy only from the closed and 'LOCKED' position. When the ejection control handle or an internal or external canopy jettison handle is pulled, the remover mechanically unlocks and jettisons the canopy. Improperly placed or unsecured items near the canopy remover may actuate the canopy jettison bellcrank, causing loss of the canopy.

## Ejection seat system

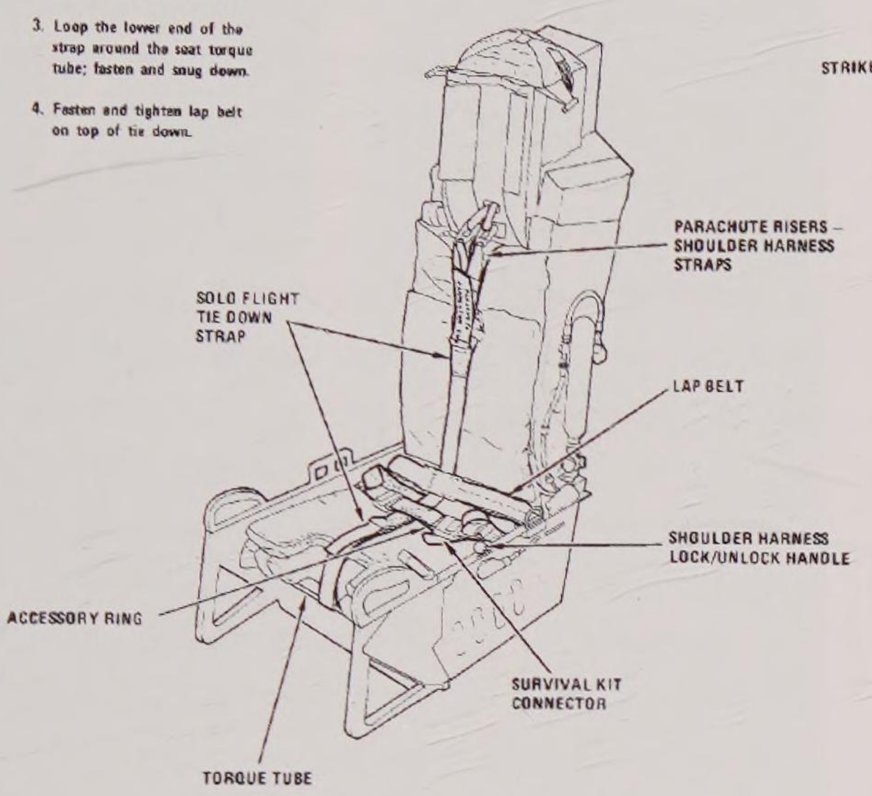
An ejection seat is installed in each cockpit and a sequencing system is provided which allows for selection of various single or dual ejection options.

Once ejection is initiated, whether dual or single, each ejection seat is a fully automatic catapult rocket system. Three ejection modes are automatically selected. Mode 1 is a low-speed mode during which the parachute is deployed almost immediately after the seat departs the aircraft. Mode 2 is a high-speed

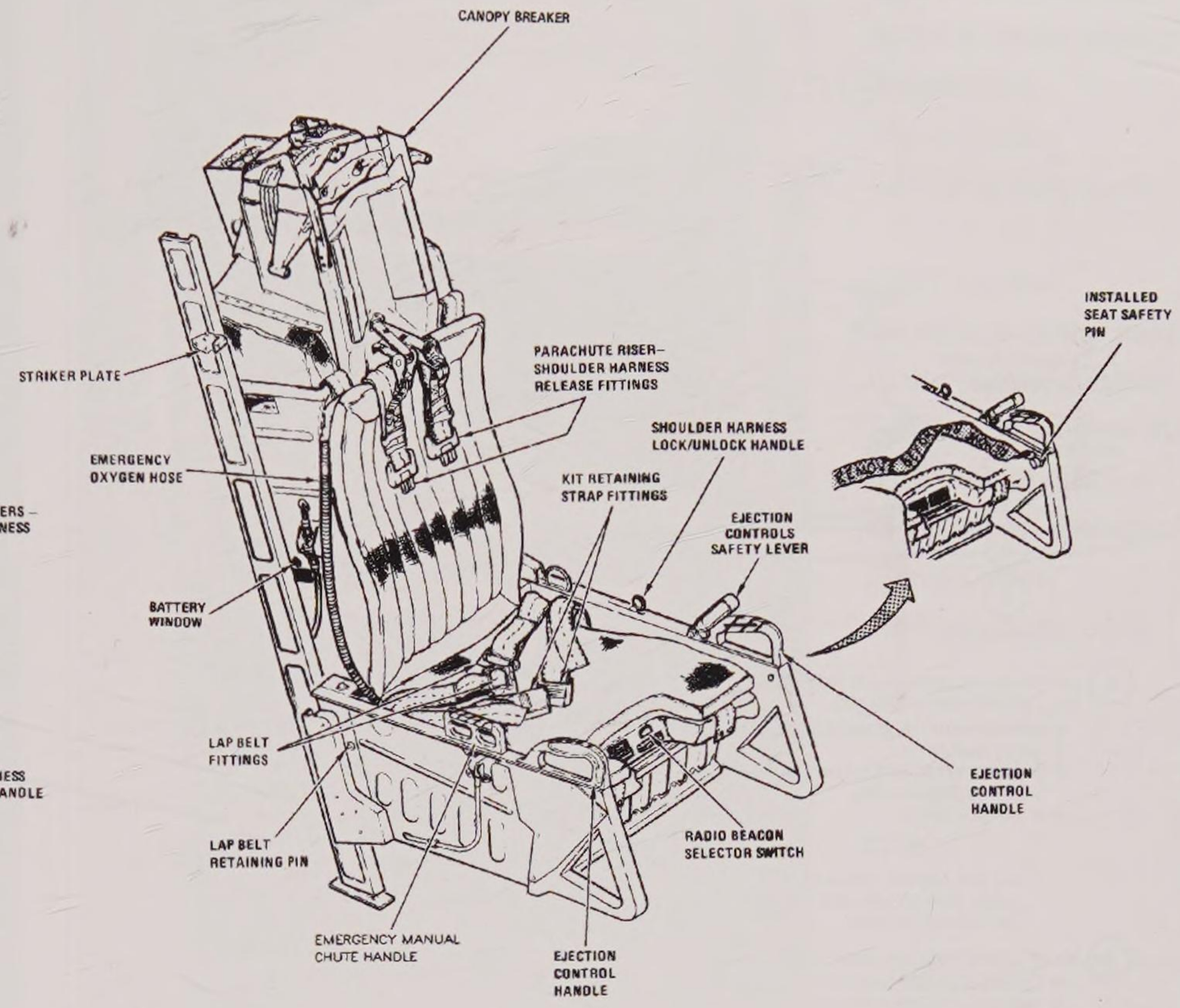
**OPPOSITE The ACES II seat is installed in all Eagles and Strike Eagles.** *(USAF)*

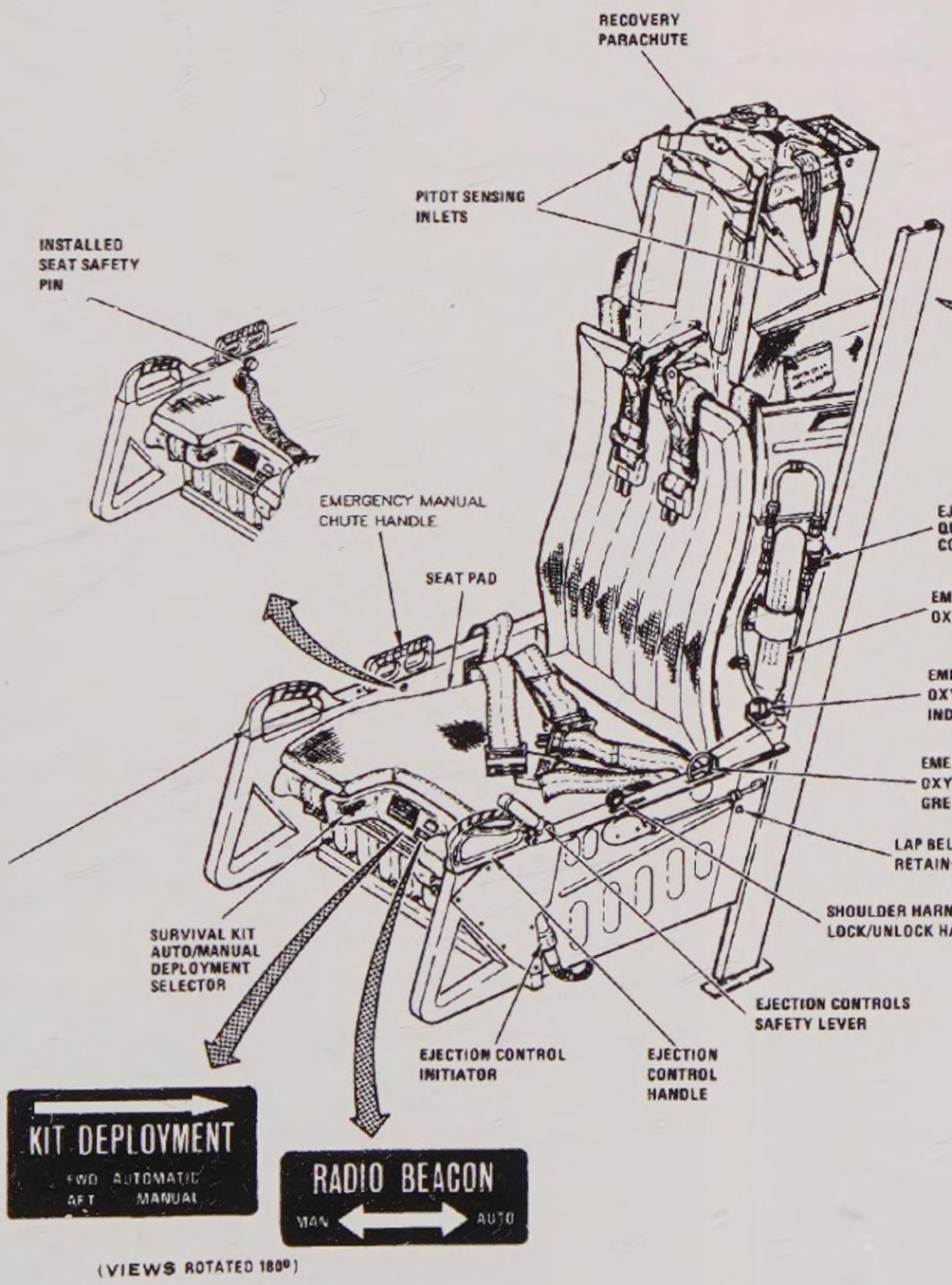
## TIE DOWN PROCEDURE

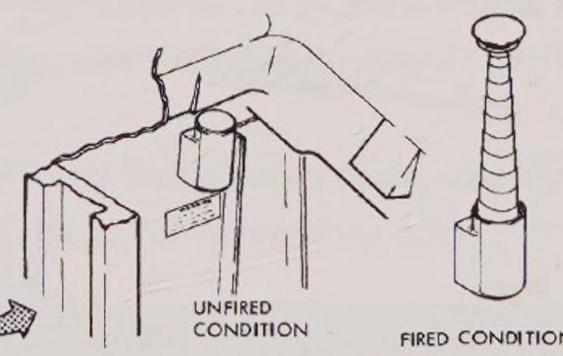
1. After orienting the strap end labeled PARACHUTE CONNECTOR END toward top of seat, attach accessory rings to survival kit; center and tighten straps.
2. Install strap end labeled PARACHUTE CONNECTOR END through both parachute/shoulder harness connectors; buckle and fully tighten strap with the shoulder harness lock/unlock handle in forward position.
3. Loop the lower end of the strap around the seat torque tube; fasten and snug down.
4. Fasten and tighten lap belt on top of tie down.



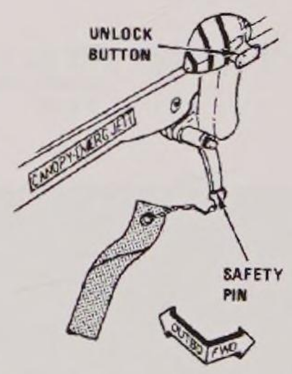

SOLO FLIGHT TIE DOWN STRAP INSTALLATION



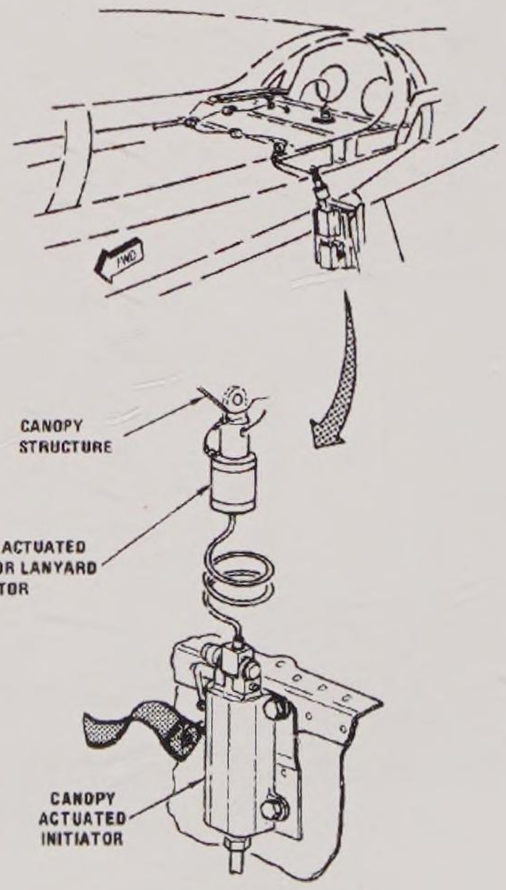



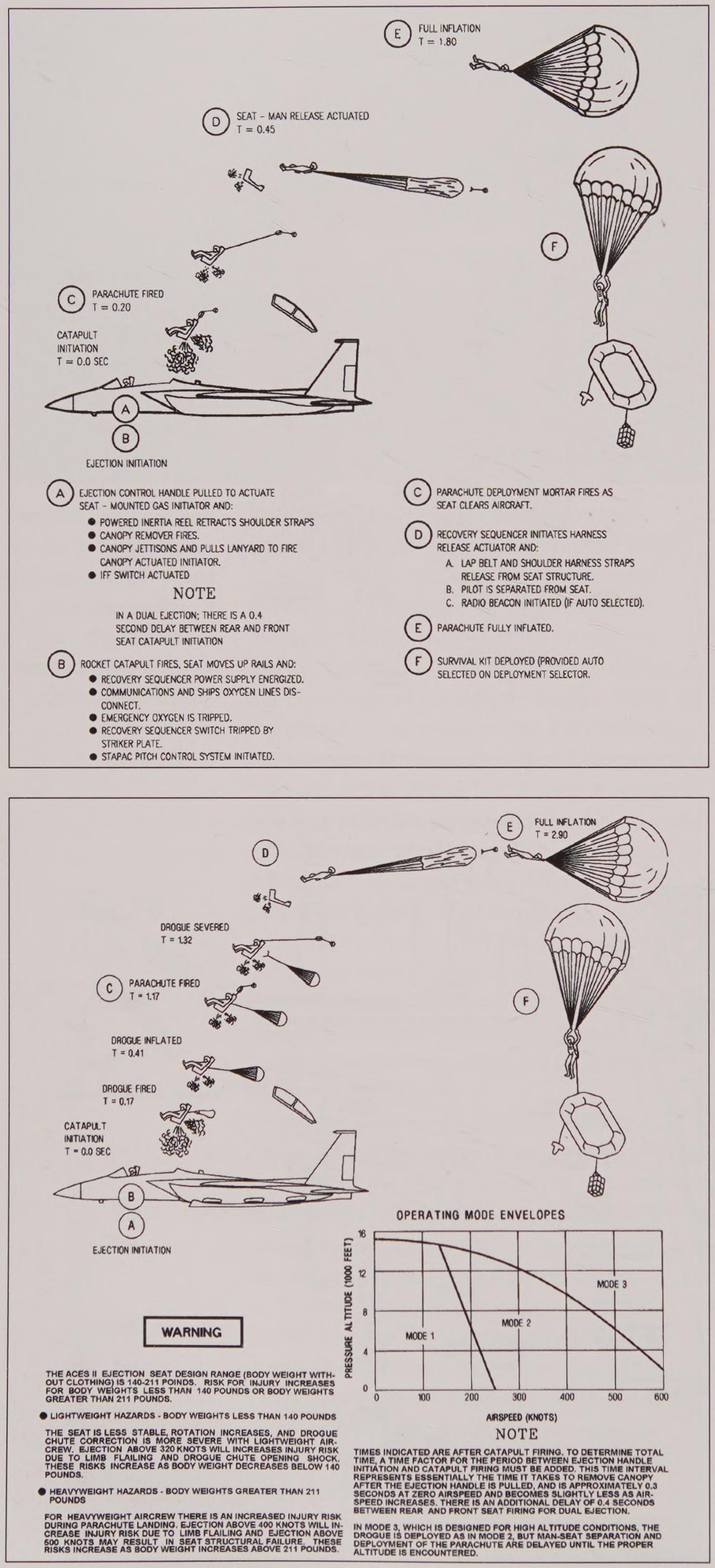




CANOPY ACTUATED INITIATOR FIRING INDICATOR




CANOPY JETTISON HANDLE




E
FULL INFLATION
T = 1.80
D
SEAT - MAN RELEASE ACTUATED
T = 0.45
F
C
PARACHUTE FIRED
T = 0.20
CATAPULT
INITIATION
T = 0.0 SEC
A
B
EJECTION INITIATION
A EJECTION CONTROL HANDLE PULLED TO ACTUATE SEAT - MOUNTED GAS INITIATOR AND:
● POWERED INERTIA REEL RETRACTS SHOULDER STRAPS
● CANOPY REMOVER FIRES.
● CANOPY JETTISONS AND PULLS LANYARD TO FIRE CANOPY ACTUATED INITIATOR.
● IFF SWITCH ACTUATED
NOTE
IN A DUAL EJECTION; THERE IS A 0.4 SECOND DELAY BETWEEN REAR AND FRONT SEAT CATAPULT INITIATION
B ROCKET CATAPULT FIRES, SEAT MOVES UP RAILS AND:
● RECOVERY SEQUENCER POWER SUPPLY ENERGIZED.
● COMMUNICATIONS AND SHIPS OXYGEN LINES DISCONNECT.
● EMERGENCY OXYGEN IS TRIPPED.
● RECOVERY SEQUENCER SWITCH TRIPPED BY STRIKER PLATE.
● STAPAC PITCH CONTROL SYSTEM INITIATED.
C PARACHUTE DEPLOYMENT MORTAR FIRES AS SEAT CLEARS AIRCRAFT.
D RECOVERY SEQUENCER INITIATES HARNESS RELEASE ACTUATOR AND:
A. LAP BELT AND SHOULDER HARNESS STRAPS RELEASE FROM SEAT STRUCTURE.
B. PILOT IS SEPARATED FROM SEAT.
C. RADIO BEACON INITIATED (IF AUTO SELECTED).
E PARACHUTE FULLY INFLATED.
F SURVIVAL KIT DEPLOYED (PROVIDED AUTO SELECTED ON DEPLOYMENT SELECTOR.
E
FULL INFLATION
T = 2.90
D
DROGUE SEVERED
T = 1.32
C
PARACHUTE FIRED
T = 1.17
DROGUE INFLATED
T = 0.41
DROGUE FIRED
T = 0.17
CATAPULT
INITIATION
T = 0.0 SEC
F
B
A
EJECTION INITIATION
OPERATING MODE ENVELOPES
PRESSURE ALTITUDE (1000 FEET)
16
12
8
4
0
0
100
200
300
400
500
600
AIRSPEED (KNOTS)
MODE 1
MODE 2
MODE 3
WARNING
THE ACES II EJECTION SEAT DESIGN RANGE (BODY WEIGHT WITHOUT CLOTHING) IS 140-211 POINDS. RISK FOR INJURY INCREASES FOR BODY WEIGHTS LESS THAN 140 POUNDS OR BODY WEIGHTS GREATER THAN 211 POUNDS.
● LIGHTWEIGHT HAZARDS - BODY WEIGHTS LESS THAN 140 POUNDS
THE SEAT IS LESS STABLE, ROTATION INCREASES, AND DROGUE CHUTE CORRECTION IS MORE SEVERE WITH LIGHTWEIGHT AIRCREW. EJECTION ABOVE 320 KNOTS WILL INCREASES INJURY RISK DUE TO LIMB FLAILING AND DROGUE CHUTE OPENING SHOCK. THESE RISKS INCREASE AS BODY WEIGHT DECREASES BELOW 140 POUNDS.
● HEAVYWEIGHT HAZARDS - BODY WEIGHTS GREATER THAN 211 POUNDS
FOR HEAVYWEIGHT AIRCREW THERE IS AN INCREASED INJURY RISK DURING PARACHUTE LANDING. EJECTION ABOVE 400 KNOTS WILL INCREASE INJURY RISK DUE TO LIMB FLAILING AND EJECTION ABOVE 500 KNOTS MAY RESULT IN SEAT STRUCTURAL FAILURE. THESE RISKS INCREASE AS BODY WEIGHT INCREASES ABOVE 211 POUNDS.
NOTE
TIMES INDICATED ARE AFTER CATAPULT FIRING. TO DETERMINE TOTAL TIME, A TIME FACTOR FOR THE PERIOD BETWEEN EJECTION HANDLE INITIATION AND CATAPULT FIRING MUST BE ADDED. THIS TIME INTERVAL REPRESENTS ESSENTIALLY THE TIME IT TAKES TO REMOVE CANOPY AFTER THE EJECTION HANDLE IS PULLED, AND IS APPROXIMATELY 0.3 SECONDS AT ZERO AIRSPEED AND BECOMES SLIGHTLY LESS AS AIRSPEED INCREASES. THERE IS AN ADDITIONAL DELAY OF 0.4 SECONDS BETWEEN REAR AND FRONT SEAT FIRING FOR DUAL EJECTION.
IN MODE 3, WHICH IS DESIGNED FOR HIGH ALTITUDE CONDITIONS, THE DROGUE IS DEPLOYED AS IN MODE 2, BUT MAN-SEAT SEPARATION AND DEPLOYMENT OF THE PARACHUTE ARE DELAYED UNTIL THE PROPER ALTITUDE IS ENCOUNTERED.

**LEFT The ACES II has multiple modes of operation. Here, Mode 1 is explained.** *(USAF)*

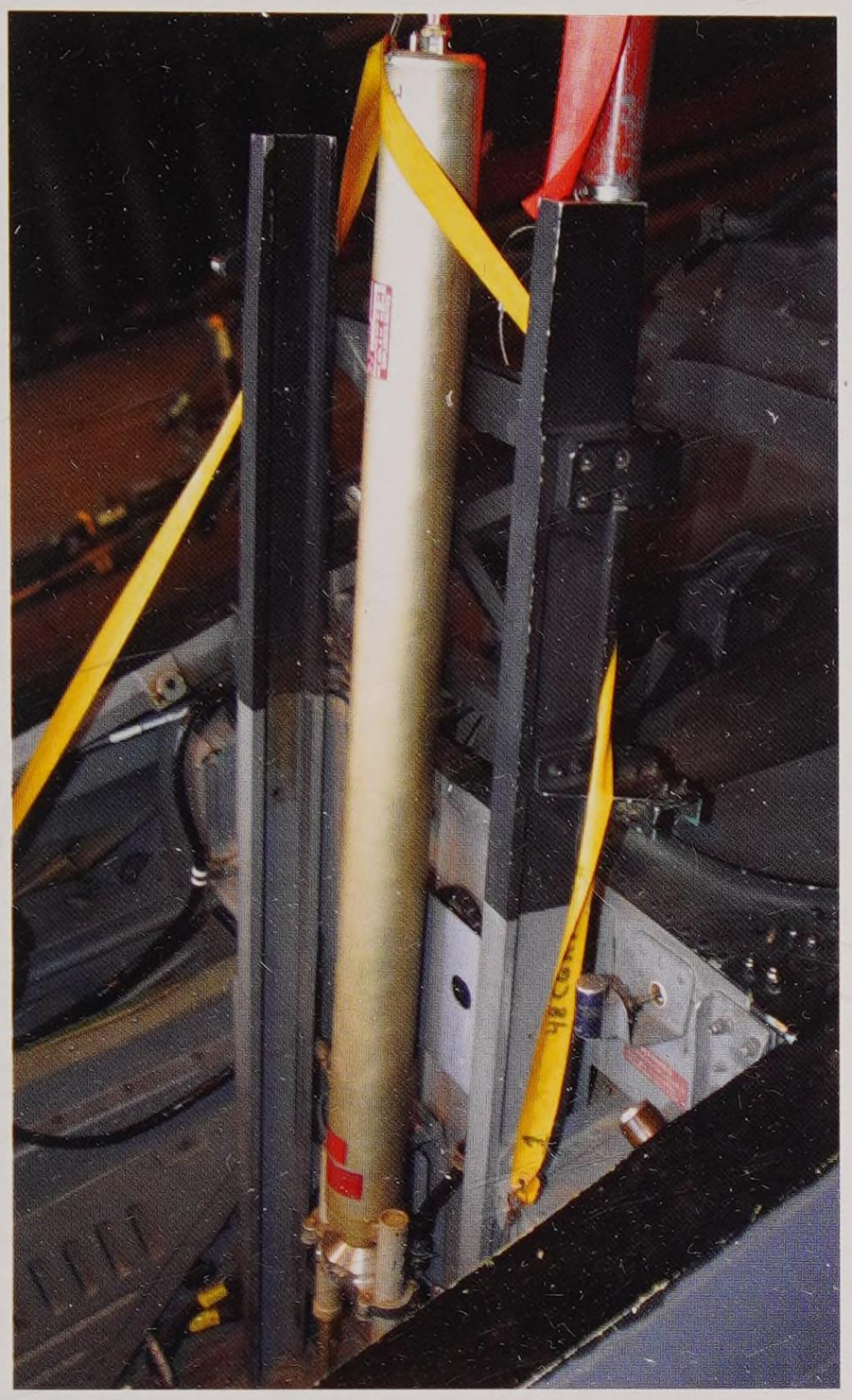
mode during which a drogue chute is first deployed to slow the seat, followed by the deployment of the parachute. Mode 3 is a high-altitude mode in which the sequence of events is the same as Mode 2 except that man–seat separation and deployment of the parachute is delayed until a safe altitude is reached.

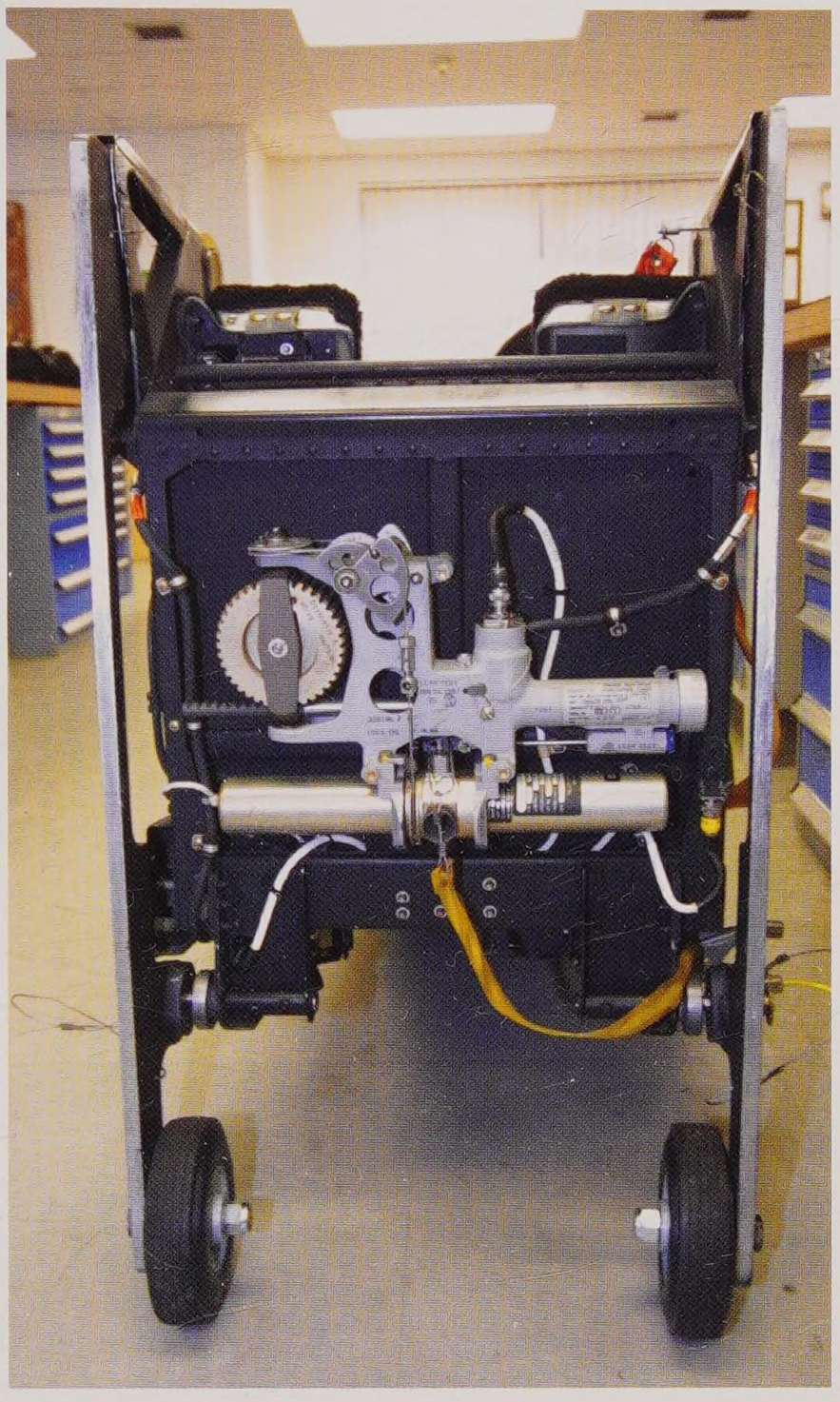
Controls are provided to adjust seat height and lock shoulder harness. The ejection seat is equipped with primary and redundant ejection systems and a canopy breaker. The primary and redundant systems are isolated and independent of each other. Both ejection systems are initiated simultaneously when an ejection control handle is pulled. However, a built-in delay in the redundant system allows the primary system to work before the redundant system starts. The time delay prevents any interference of primary and redundant system ejection sequencing. Also, if the primary system fails prior to canopy jettison, the redundant system will jettison the canopy and eject the seat.

If both the primary and redundant system fail to jettison the canopy, the redundant system will still fire the seat catapults, and with the addition of the seat-mounted canopy breaker, provide through-the-canopy ejection. The redundant system will eject the seat regardless of canopy position (open, closed or in between).

The seawater-activated release system (SEAWARS) provides an automatic backup method to release the parachute canopy when landing in seawater. SEAWARS consist of two releases mounted outboard of the Koch connectors on the parachute risers. Each release contains an electronics package (sensor), battery, cartridge, and canopy-release fitting. Immersion in seawater activates the sensors which mechanically release the parachute risers from the aircrew's restraint harness. With SEAWARS installed, the normal procedures for connecting and releasing the Koch fitting are the same.

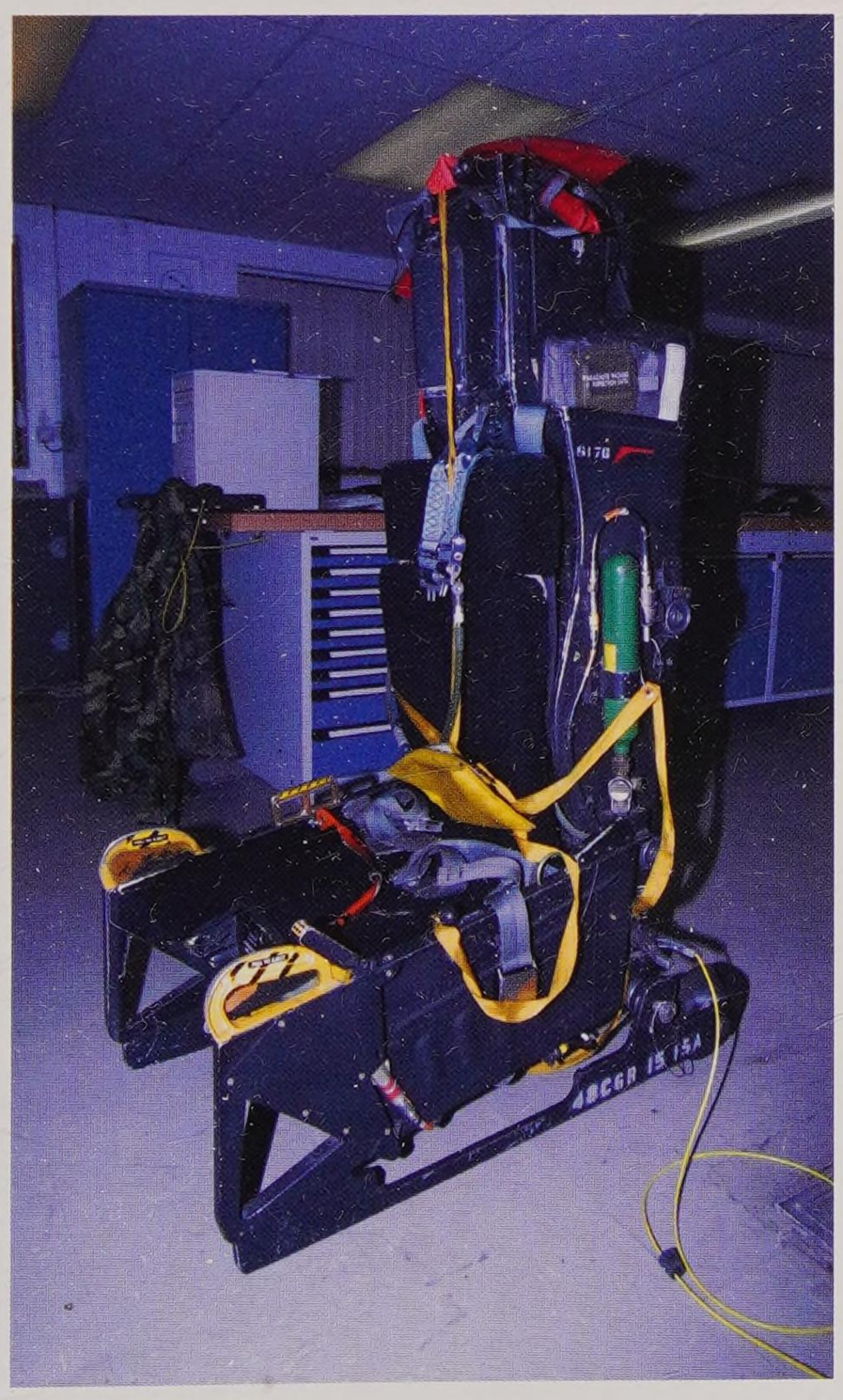
**LEFT Here, Mode 2 is explained.** *(USAF)*





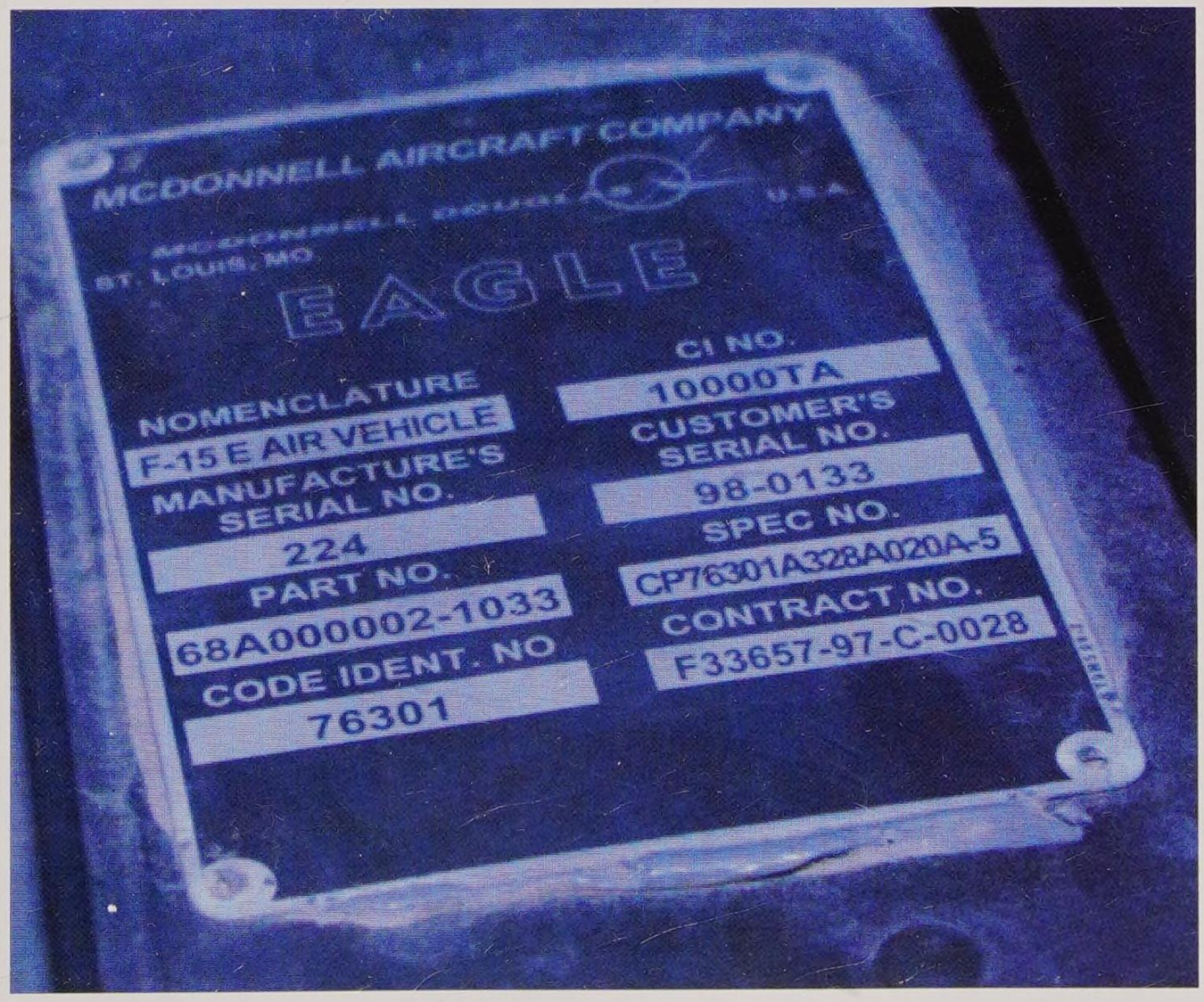
**FAR LEFT The rails into which the ACES II slides during installation.** *(Steve Davies/ FJPhotography.com)*

**LEFT On the underside of the seat is the rocket exhaust. This pivots to give the seat stability during the ejection sequence.** *(Steve Davies/ FJPhotography.com)*



**LEFT Out for maintenance, an ACES II sits in the pyro shop at RAF Lakenheath.** *(Steve Davies/FJPhotography.com)*

**BELOW Every Eagle has a name plate, usually located at the rear of the canopy.** *(Steve Davies/FJPhotography.com)*



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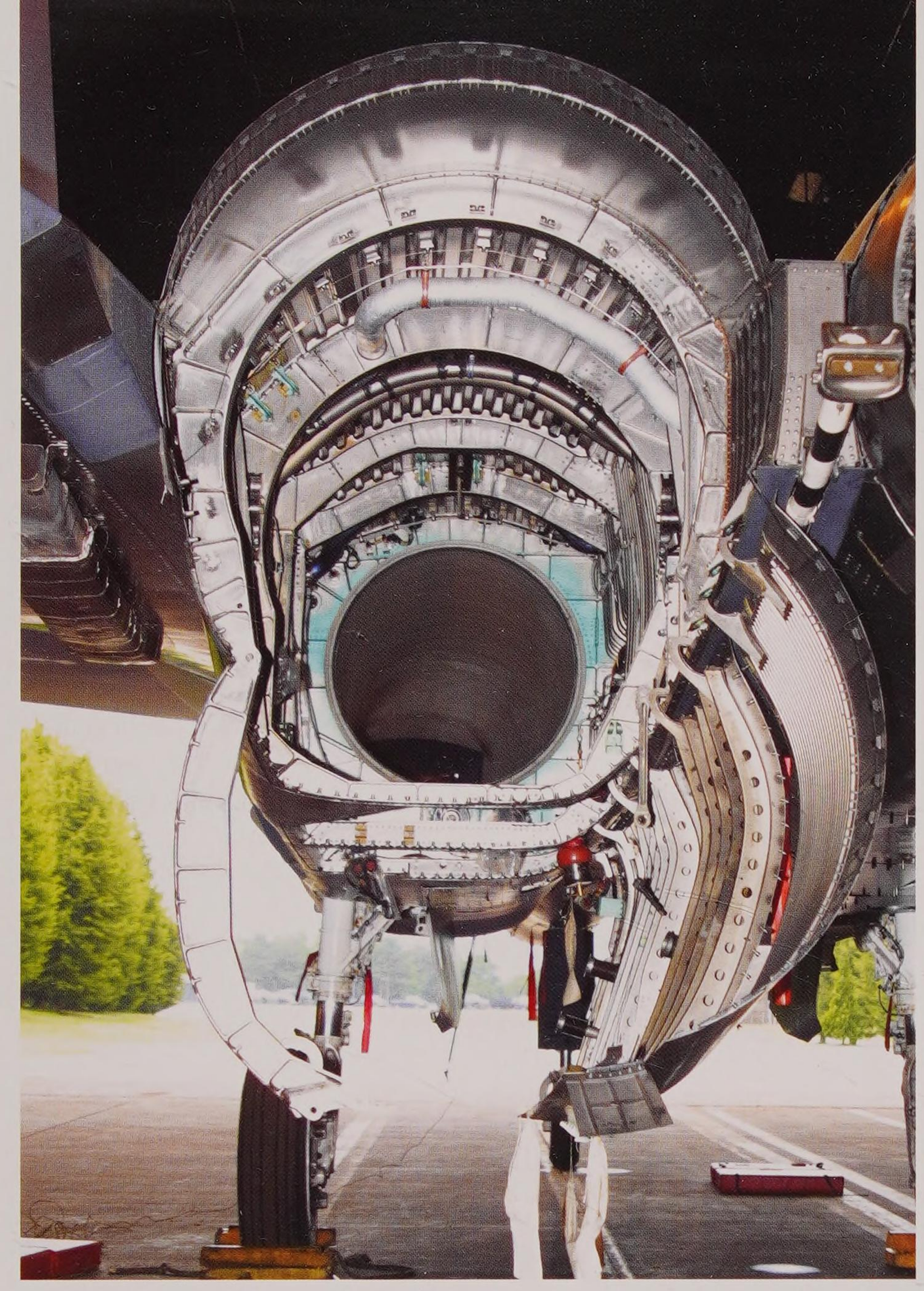
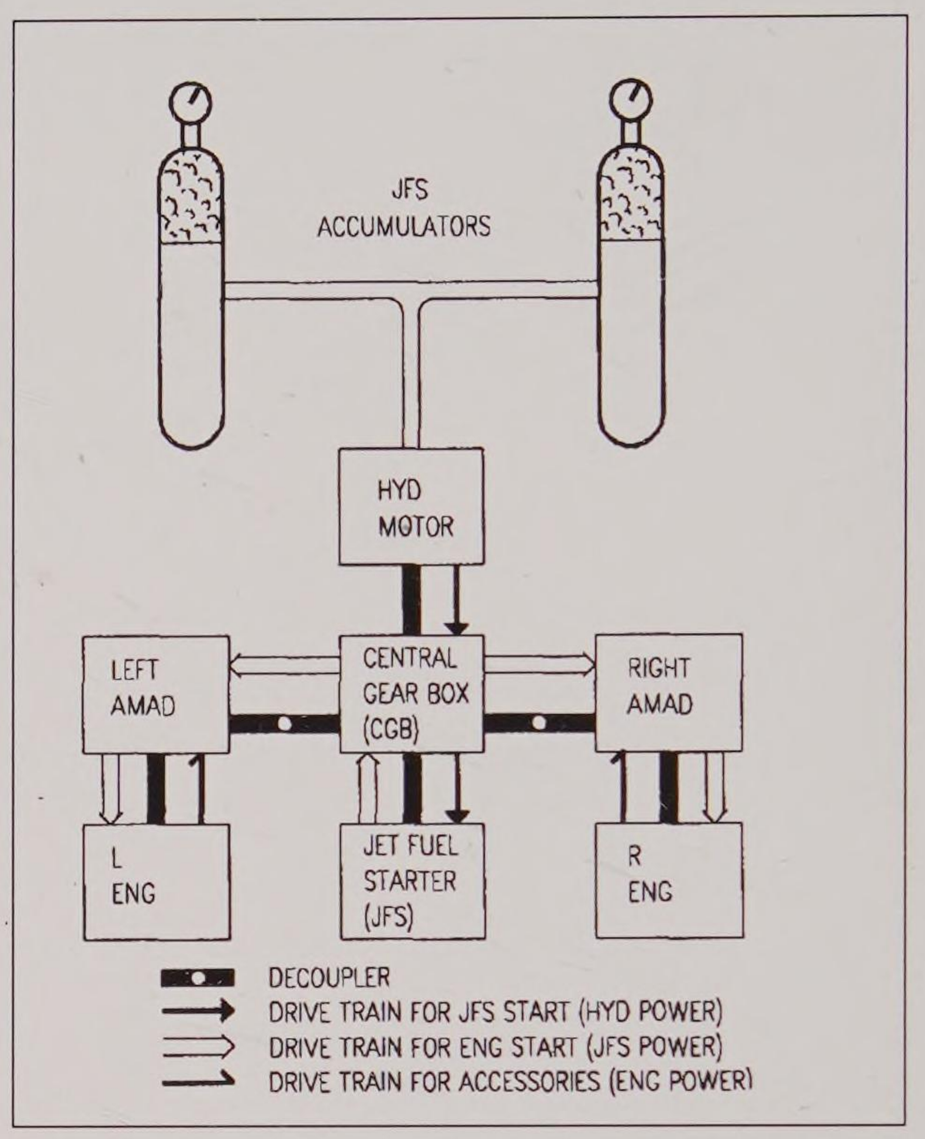
*Chapter Four*

# The Pratt & Whitney F100-PW-229

**In USAF service, the F-15E is powered by either two Pratt & Whitney F100-PW-220 or two F100-PW-229 turbofan engines with afterburners. The text that follows will focus on the PW-229, which is controlled by an improved digital electronic engine control (IDEEC). The IDEEC automatically trims to maintain performance as the engine deteriorates.**

**OPPOSITE A Strike Eagle equipped with a PW-229 generates almost 60,000lb of thrust in full afterburner, as seen here.**
*(Steve Davies/FJPhotography.com)*





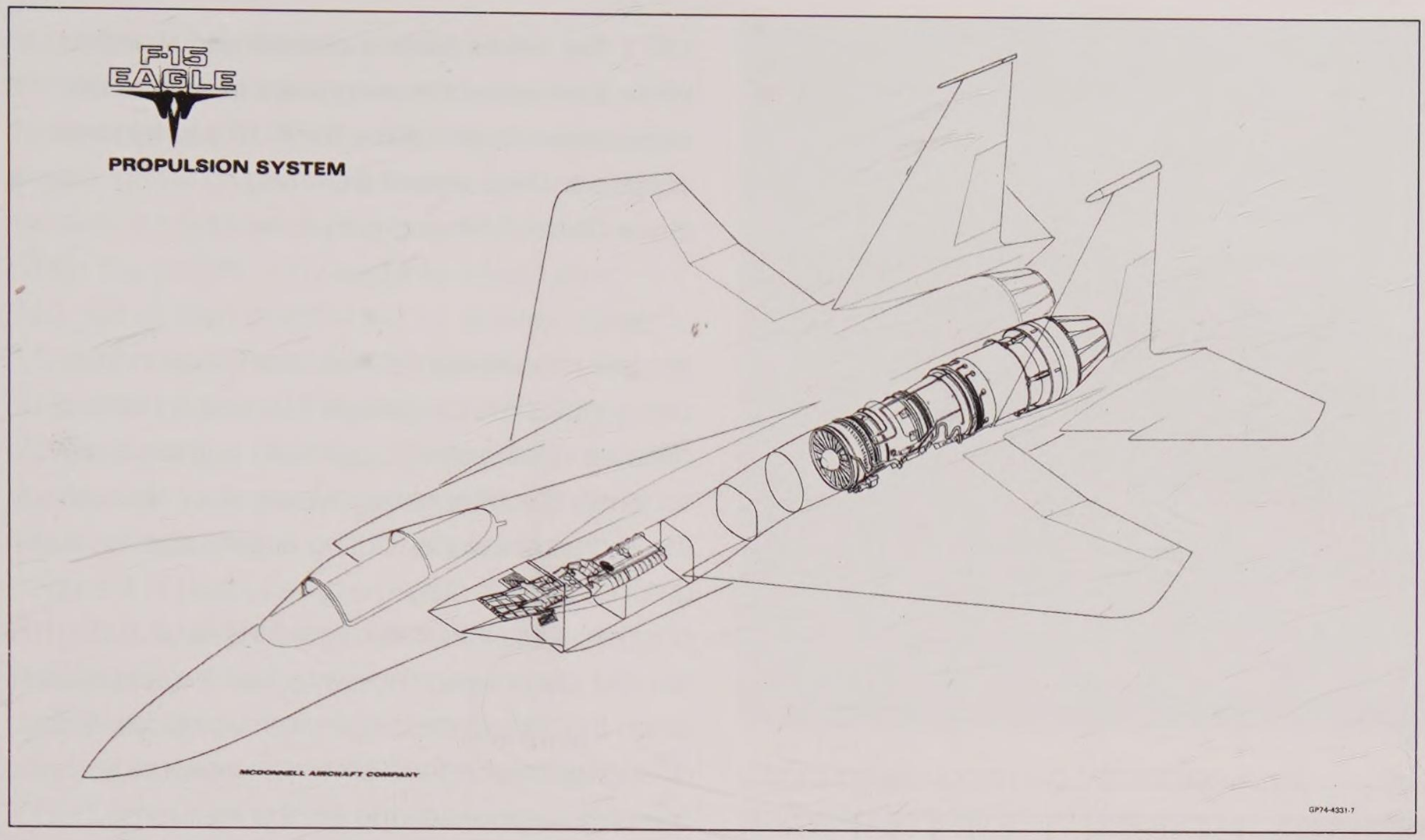

**ABOVE The jet fuel starter is used to crank the F-15 engines.** *(USAF)*

## Engine starting system

A self-contained JFS is used to crank the engines for starting. The JFS is a small jet engine mounted on the central gearbox, and along with the airframe-mounted accessories drive (AMAD) provides rotation and initial

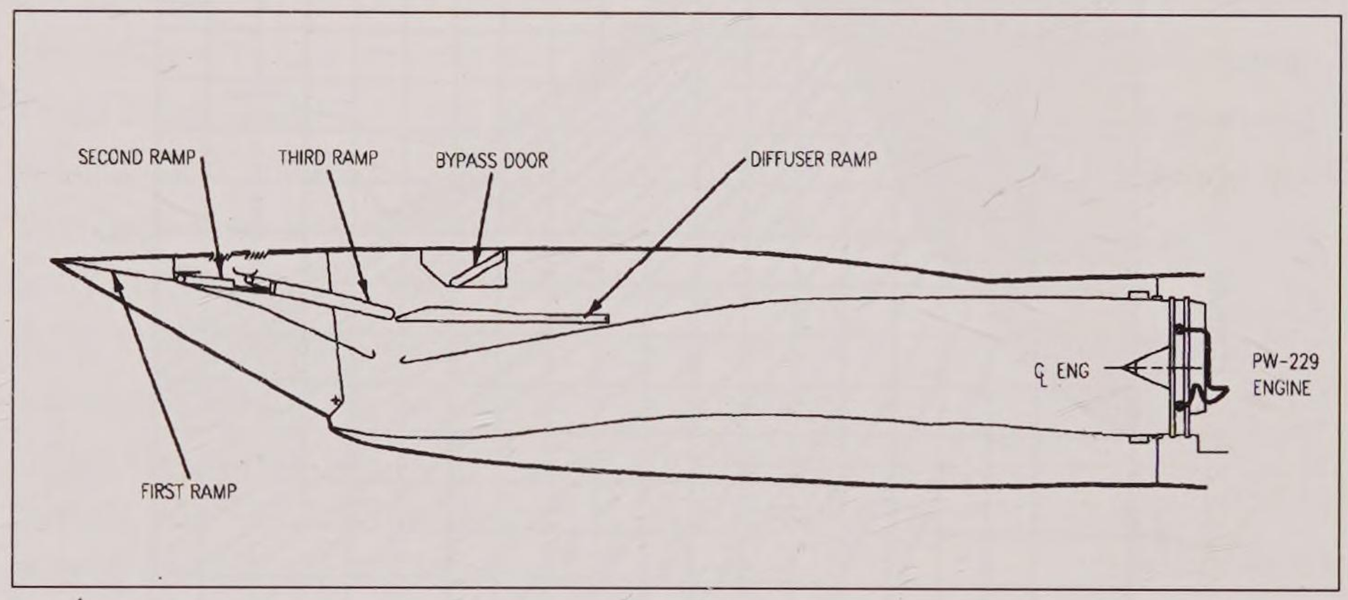
**ABOVE The engine bay in the F-15E can accommodate PW and GE engines. Seen here with the lower doors open and the engine removed, the majority of the material on show is titanium.** *(Steve Davies/ FJPhotography.com)*

**RIGHT By contrast an F-15C with PW-220 engines is down by about a third, at a total thrust of 40,000lb.** *(Steve Davies/ FJPhotography.com)*




**LEFT The Eagle's propulsion system consists of the induction and inlet system and the F100 or GE110 engine.** *(Boeing)*

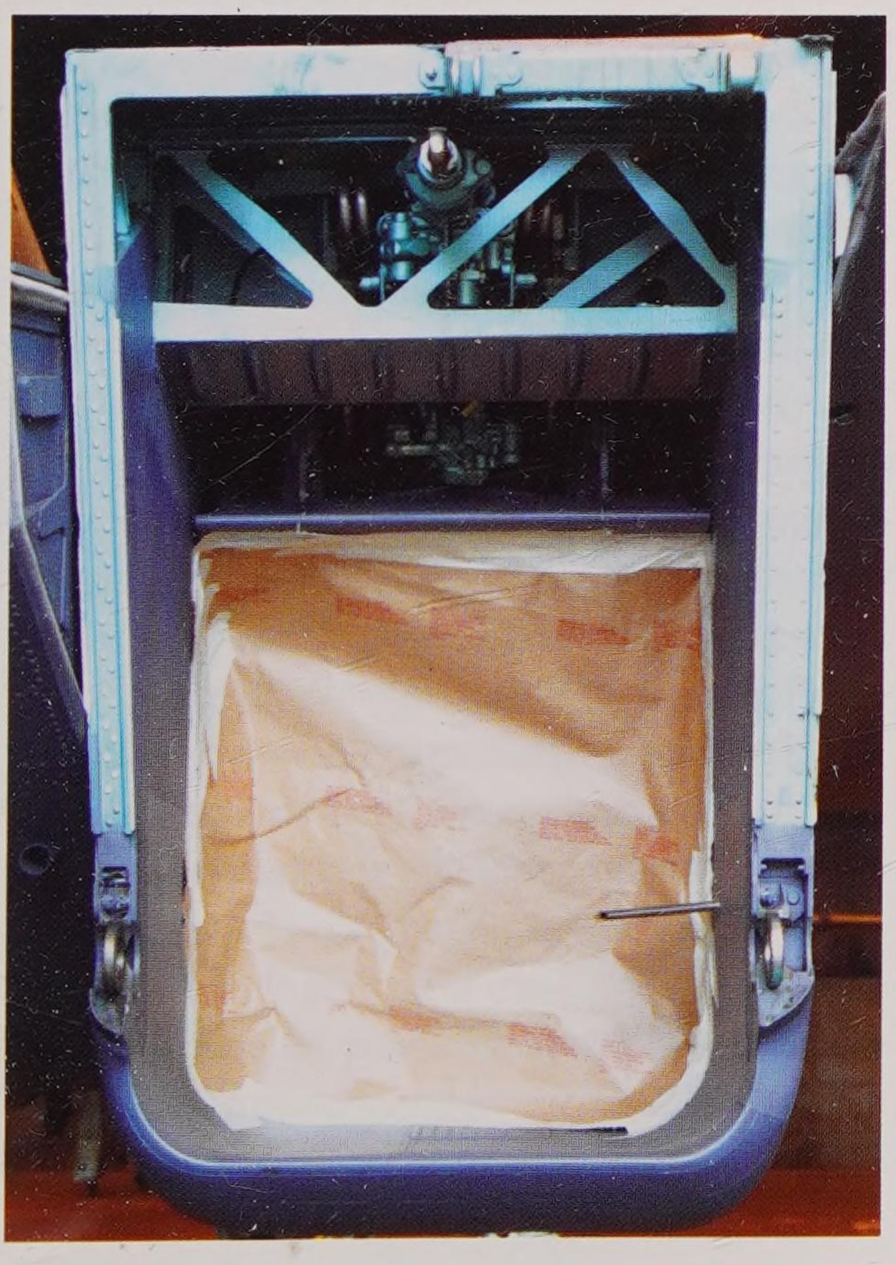
**BELOW A series of ramps and a single bypass door control the airflow into each engine. Smooth airflow results in smooth engine operation.** *(USAF)*



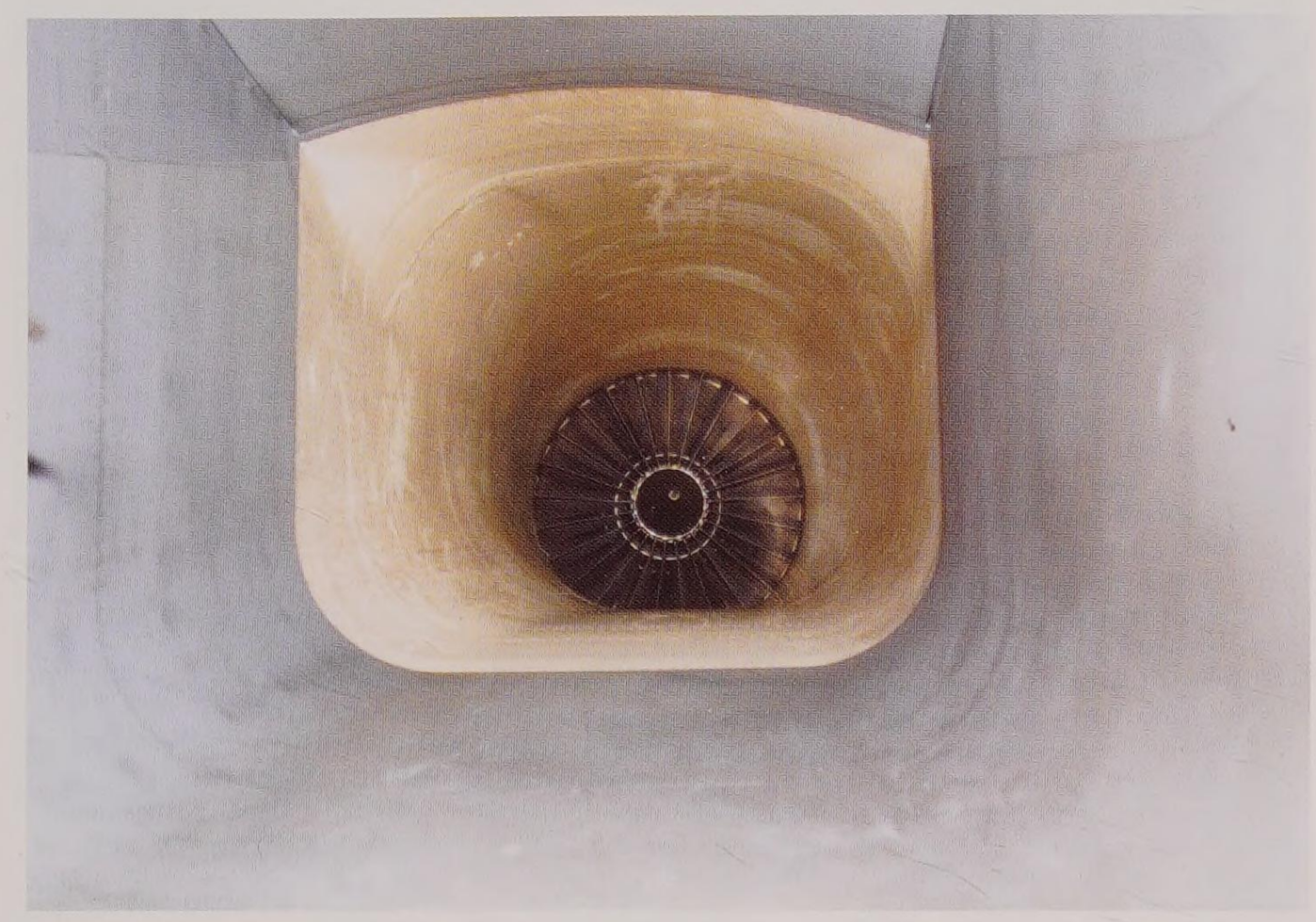

electrical power for start-up. The JFS itself is started by accumulated hydraulic pressure. External power is not required during engine start. The JFS provides the only means of engine rotation for start-up.

## Air induction

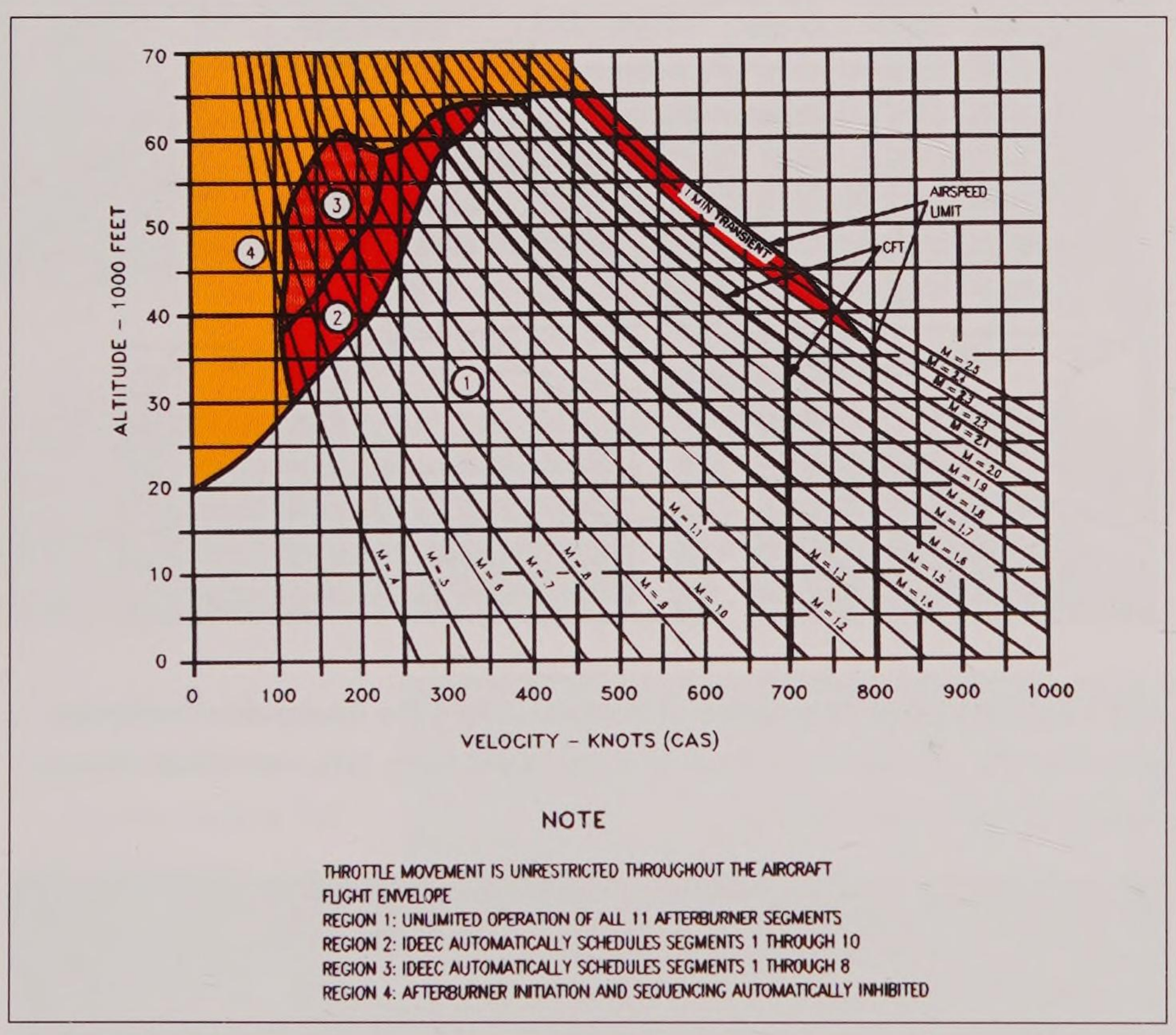
The two independent air induction systems consist of three variable ramps, a variable diffuser ramp, and a variable bypass door. The left/right



**LEFT AND BELOW This series of images shows the intake door removed, revealing the second ramp (fore, top) and third ramp (aft, extended).** *(Steve Davies/FJPhotography.com)*



**LEFT The intake itself is smooth and straight. While this makes for unimpeded airflow to the compressor, it also gives the F-15 a hefty radar signature when viewed front on.** *(Steve Davies/FJPhotography.com)*




| GROUND | | | | |
|---|---|---|---|---|
| **CONDITION** | **FTIT °C** | **RPM%** | **OIL PSI** | **REMARKS** |
| START | 800 | - | - | NOTE 4 |
| IDLE | 625 | - | 15-95 | NOTE 4 |
| MILITARY/AB | 1070 | 97 | 30-95 | NOTE 1, 4, 5, 7, 8, AND 11 |
| TRANSIENT | 1090 | 98 | 30-95 | NOTE 1, 4, 7 AND 9 |
| FLUCTUATION | ±10 | ±1 | IDLE ±5<br>ABOVE IDLE ±10 | NOTE 1, 2, 3, AND 5 |
| **FLIGHT** | | | | |
| AIRSTART | 870 | - | - | |
| IDLE | - | - | 15-95 | |
| MILITARY/AB | 1070 | 97 | 30-95 | NOTE 1, 6, AND 12 |
| TRANSIENT | 1090 | 98 | 30-95 | NOTE 1 AND 10 |
| FLUCTUATION | ±10 | ±1 | IDLE ±5<br>ABOVE IDLE ±10 | NOTE 1, 2, 3 AND 5 |

air data processors (ADPs), one for each inlet, use angle of attack, aircraft Mach number and other air data system outputs to automatically schedule the ramps and bypass door throughout the aircraft envelope. During engine start on the ground, the first stage ramp is locked in the up position. If the inlet ramp switch is in 'AUTO', the first stage ramp moves to the down position when the associated engine rpm is above JFS disengagement speed and main generator power is available. In the air, the inlet ramp system still operates when the engine is shut down as long as the other engine is operating and main generator power is available. The left and right inlet systems utilise UTL A and UTL B, respectively, for hydraulic power.

## Variable ramps

The variable ramps provide air, at optimum subsonic flow, to the face of the engine fan inlet throughout a wide range of aircraft speeds. Ramp position is controlled by the left/right ADPs.

## Bypass door

The bypass door automatically relieves excess pressure in the inlet duct. The left/right ADPs position the bypass doors.

## Engine oil system

Each engine is equipped with a completely self-contained oil system. Oil is supplied to the main pump element by gravity feed. Return of the engine oil to the pump reservoir is severely limited during 0 or negative g flight.

## Engine fuel ignition

The ignition system contains an independent engine-mounted generator and four igniter

**CENTRE PW-229 airspeed and AB operating envelope.** *(USAF)*

**LEFT PW-229 engine limitations.** *(USAF)*

plugs (two for the engines and two for the afterburners). During engine start, moving the throttle from 'OFF' to 'IDLE' causes the engine igniter plugs to discharge. Ignition then remains continuous during engine operation. When the throttle is moved into afterburner (AB), AB ignition is activated for approximately 3.5 seconds. Ignition is automatically recycled, up to three times, in the event of a no-light or blowout, without retarding the throttle to military power (MIL – maximum power without use of reheat/afterburner).

## Engine control system

The engine control consists primarily of a hydromechanical main fuel control (MFC), afterburner fuel control (AFC) and a full authority IDEEC. The engine control uses a digital primary control (PRI) with a backup hydromechanical secondary control (SEC). The secondary mode can be achieved either by an automatic primary mode fault action or by the pilot manually selecting 'OFF' on the cockpit 'ENG CONTR' switch. During SEC mode operation, afterburner is inhibited and engine thrust is limited to 70–80% MIL power in primary mode. The pilot can attempt to restore primary mode operation by cycling the 'ENG CONTR' switch. If the fault that caused the transfer has cleared, the engine will return to primary mode.

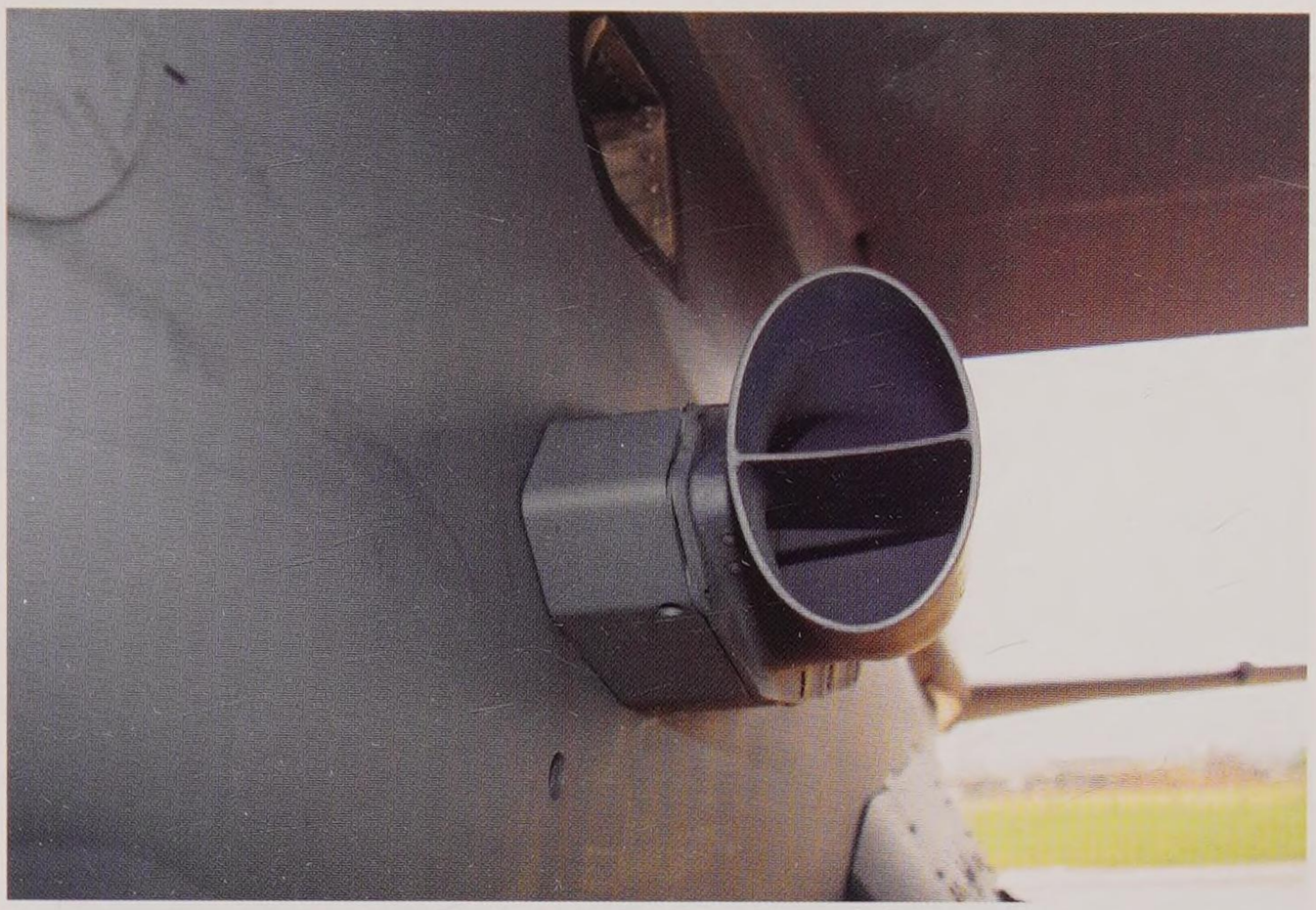
## Improved digital electronic engine control

The IDEEC contains the engine operating schedules for automatic control from 'IDLE' to 'MAX AB', and is powered by the engine alternator. The IDEEC schedules engine and afterburner fuel flows, the compressor inlet variable vanes (CIVVs), rear compressor variable vanes (RCVVs), start bleed position, anti-ice and nozzle position. The IDEEC controls engine performance by scheduling engine fuel flow to control airflow, and nozzle position to control engine pressure ratio (EPR). EPR is the ratio between engine exhaust pressure and engine inlet pressure. By controlling airflow and EPR the engine performance is maintained at a consistent level for a new or deteriorated engine until the fan turbine inlet temperature (FTIT) limit is reached.

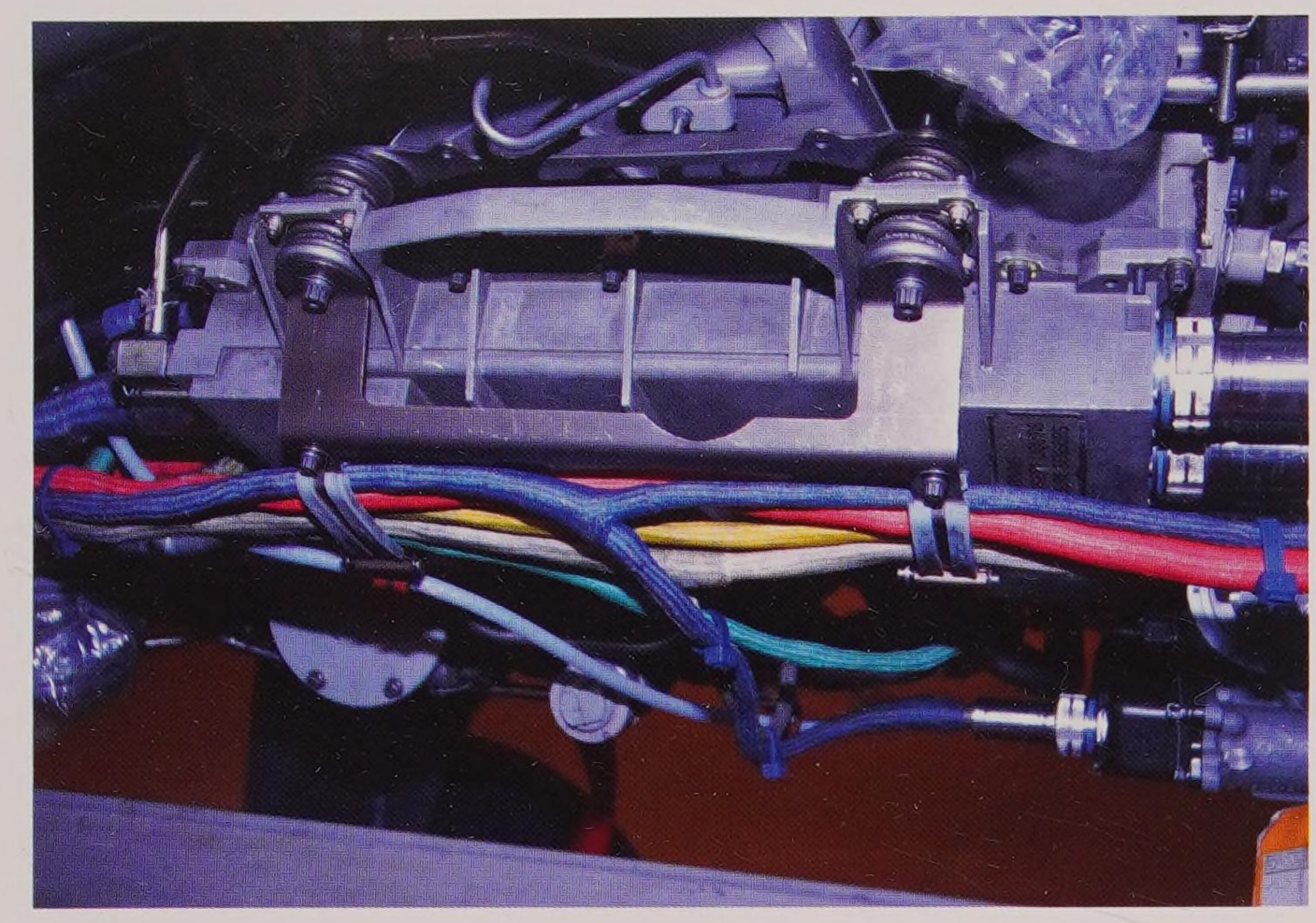
If the IDEEC detects a failure that prevents it from safely controlling the engine it will automatically switch to the secondary mode, the same as 'ENG CONTR' switch 'OFF'. In this mode afterburner operation is inhibited, thrust is limited, the CIVVs are in the fully closed position, the nozzle is closed to the minimum area (less than 5%) and the 'L ENG CONTR' or 'R ENG CONTR' caution is displayed. The RCVVs, start bleeds and engine fuel flow are scheduled by the MFC. The engine will remain in this mode until the failure clears and the left or right 'ENG CONTR' switch is cycled. The engine can be started with the left or right 'ENG CONTR' switch 'ON' or 'OFF'. The 'ENG CONTR' switch position should not be changed within 90 seconds after advancing the throttle to 'IDLE'. If the start is made with the switches 'OFF' or the IDEEC reverts to the secondary mode, ground-starting time will be longer.

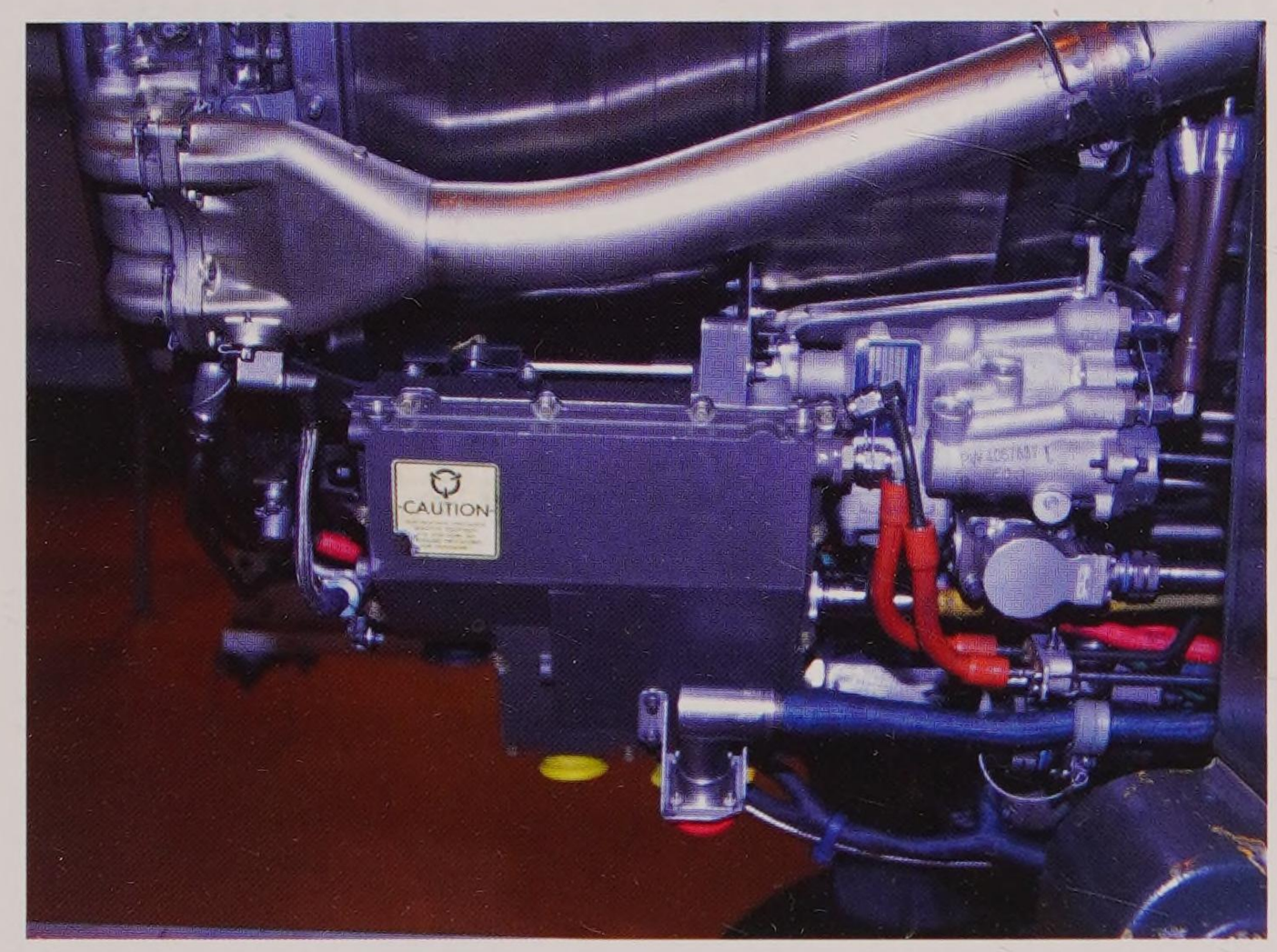
The IDEEC includes a ground idle thrust (GIT) setting to maintain engine taxi performance. GIT is automatically activated with the aircraft on the ground and throttles near idle. Acceleration from ground idle to MIL will be approximately one second longer than from approach or flight idle. Following engine ground start whenever the landing gear handle is 'DN', and for nine minutes after the landing handle is set to 'UP', the IDEEC may position the RCVVs more closed for increased stall margin.

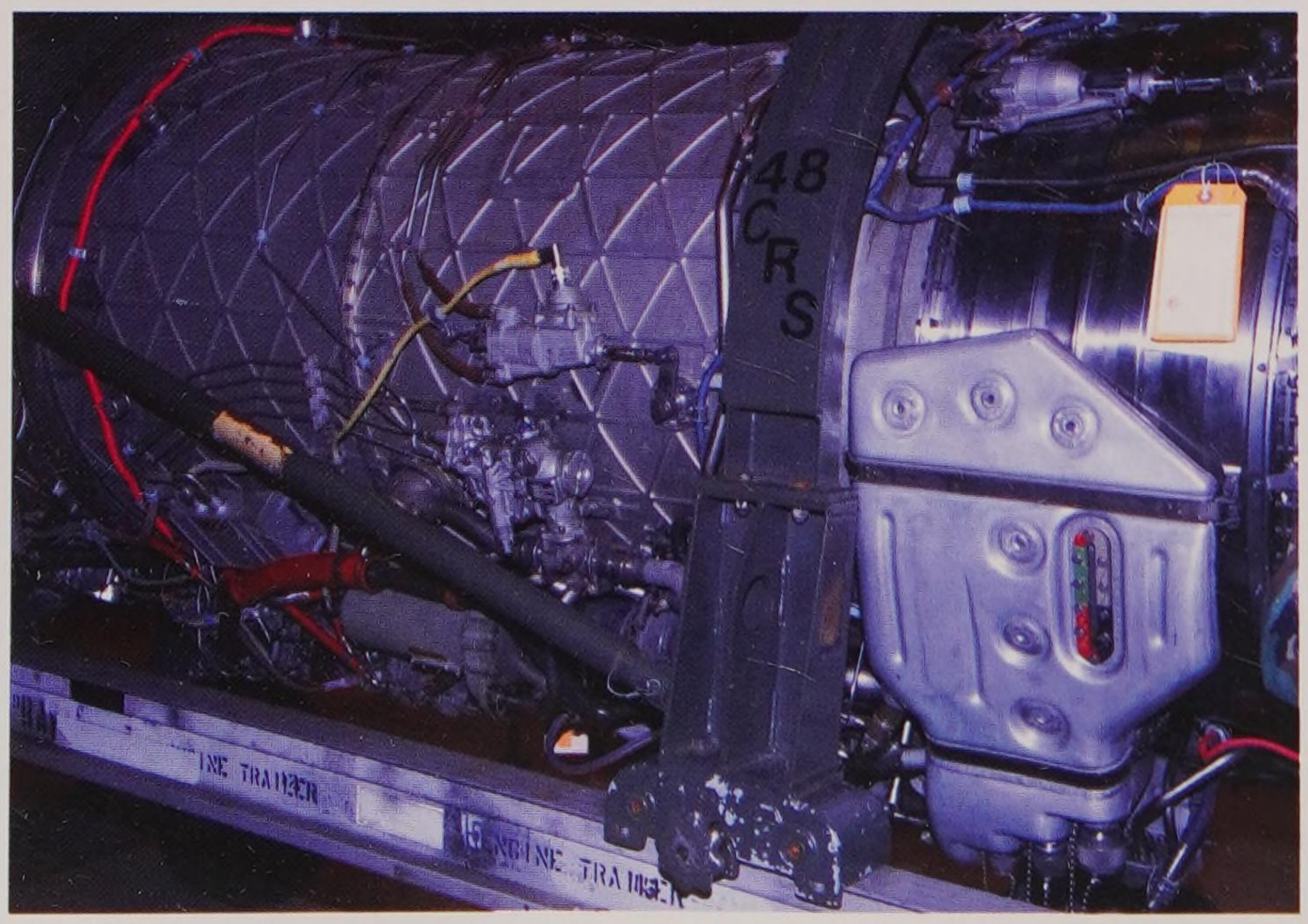
Positioning the RCVVs more closed results in up to 2% higher engine rpm at MIL and above. Three minutes after setting the landing gear handle to 'UP', engine rpm may decrease up to 2%. The IDEEC also includes transient idle



**ABOVE For F-15Es equipped with the PW-229, the increased cooling requirements of the engine demand a bigger air scoop on the left CFT.** *(Steve Davies/ FJPhotography.com)*






**LEFT Accessory gearboxes are attached to the engine and used to drive critical aircraft systems.** *(Steve Davies/FJPhotography.com)*

control logic. After a snap decel, engine speed will initially decrease to approximately 79% rpm, while thrust decreases to the requested throttle setting. If the throttle is not advanced for 20 seconds, engine speed will then further decrease and stabilise at a steady-state idle rpm with no additional thrust decrease. This control feature extends engine life and improves cycle (MAX-IDLE-MAX and MIL-IDLE-MIL) response times.

## Main fuel control

The MFC houses the hydromechanical components that are controlled by the IDEEC in the 'ENG CONTR ON' mode. If the IDEEC is transferred to the secondary mode or the 'ENG CONTR' switch is 'OFF', the MFC schedules the engine fuel flow, start bleed position and RCVV position hydromechanically in response to throttle movement, inlet static pressure and engine inlet total temperature.

## Engine monitoring system

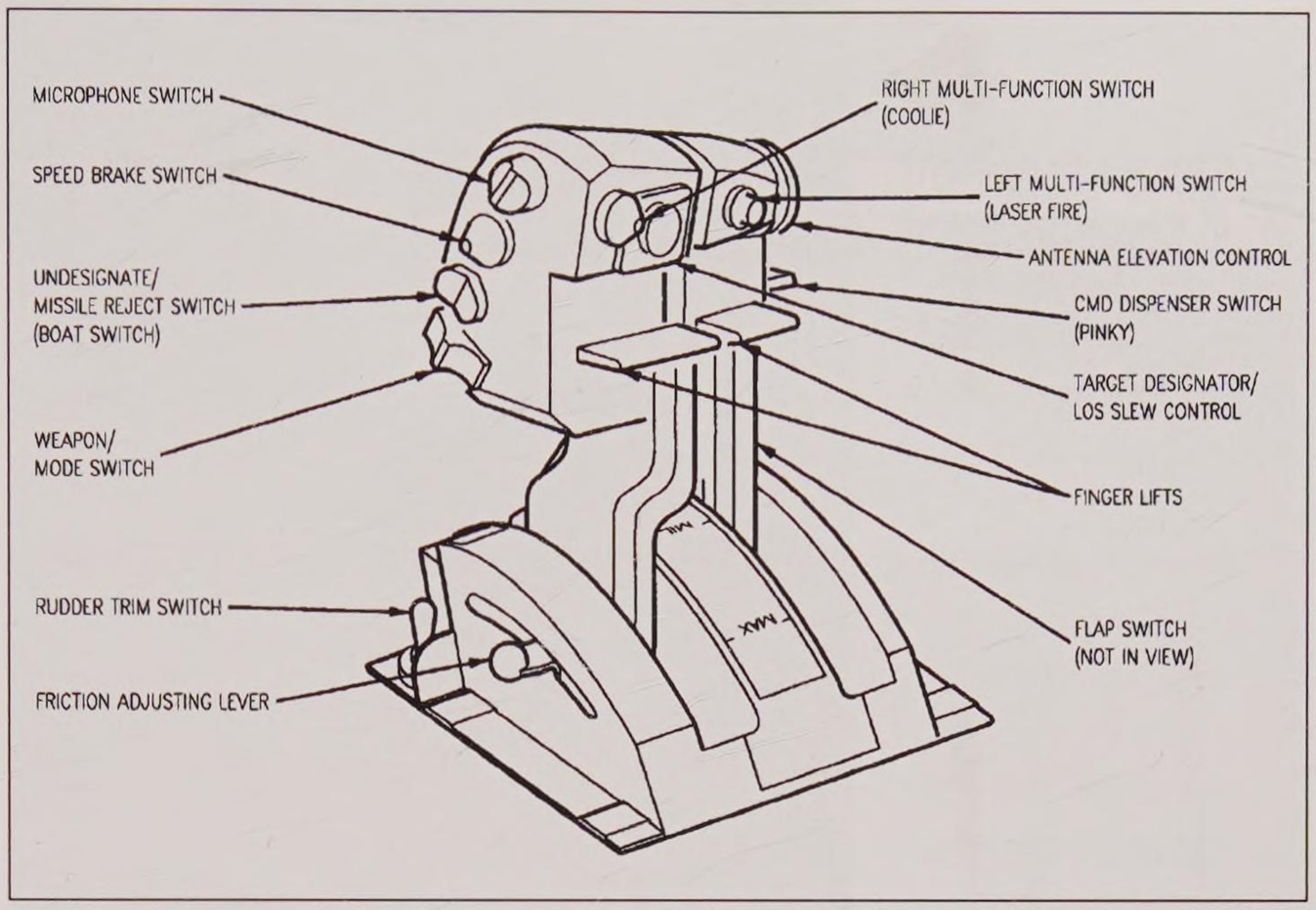
The engine incorporates an engine monitoring system which consists of the IDEEC and the engine diagnostic unit (EDU).

The IDEEC and EDU continuously monitor electrical control components and engine operation to detect engine failures. Abnormal engine operation and either intermittent or hard failures of components are detected and flagged for maintenance. During abnormal engine operation or component failure, the EDU will record engine and aircraft data as an aid to maintenance troubleshooting.

The EDU also maintains engine life cycle information. Airframe-mounted 'LEFT ENGINE' or 'RIGHT ENGINE' and 'L ENG MON SYS' or 'R ENG MON SYS' fail indicators, located on the avionics status panel in the nose wheel-well, are latched if a fault is detected that requires maintenance attention.

## Afterburner system

The afterburner has 11 segments that are progressively selected as the throttle is advanced

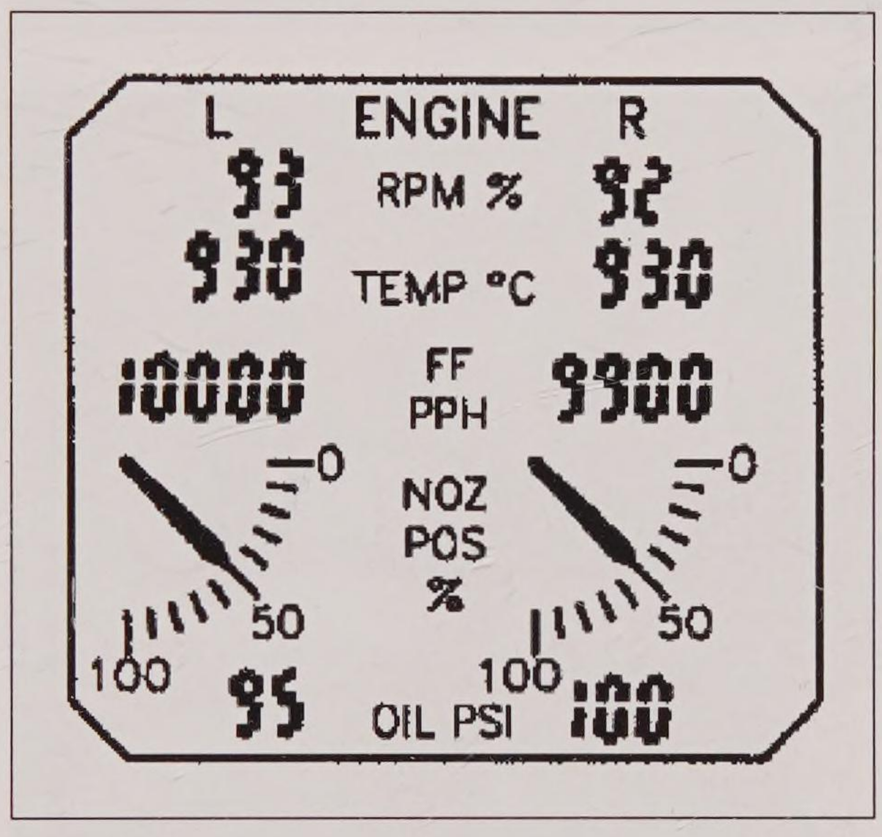



**RIGHT The front cockpit throttle quadrant has finger lifts that must be pulled up to allow the engine to be started or shut down. A position between 'IDLE' and 'IDLE SHUT OFF' prevents the throttle being moved fore or aft unless these lifts are raised.** *(USAF)*

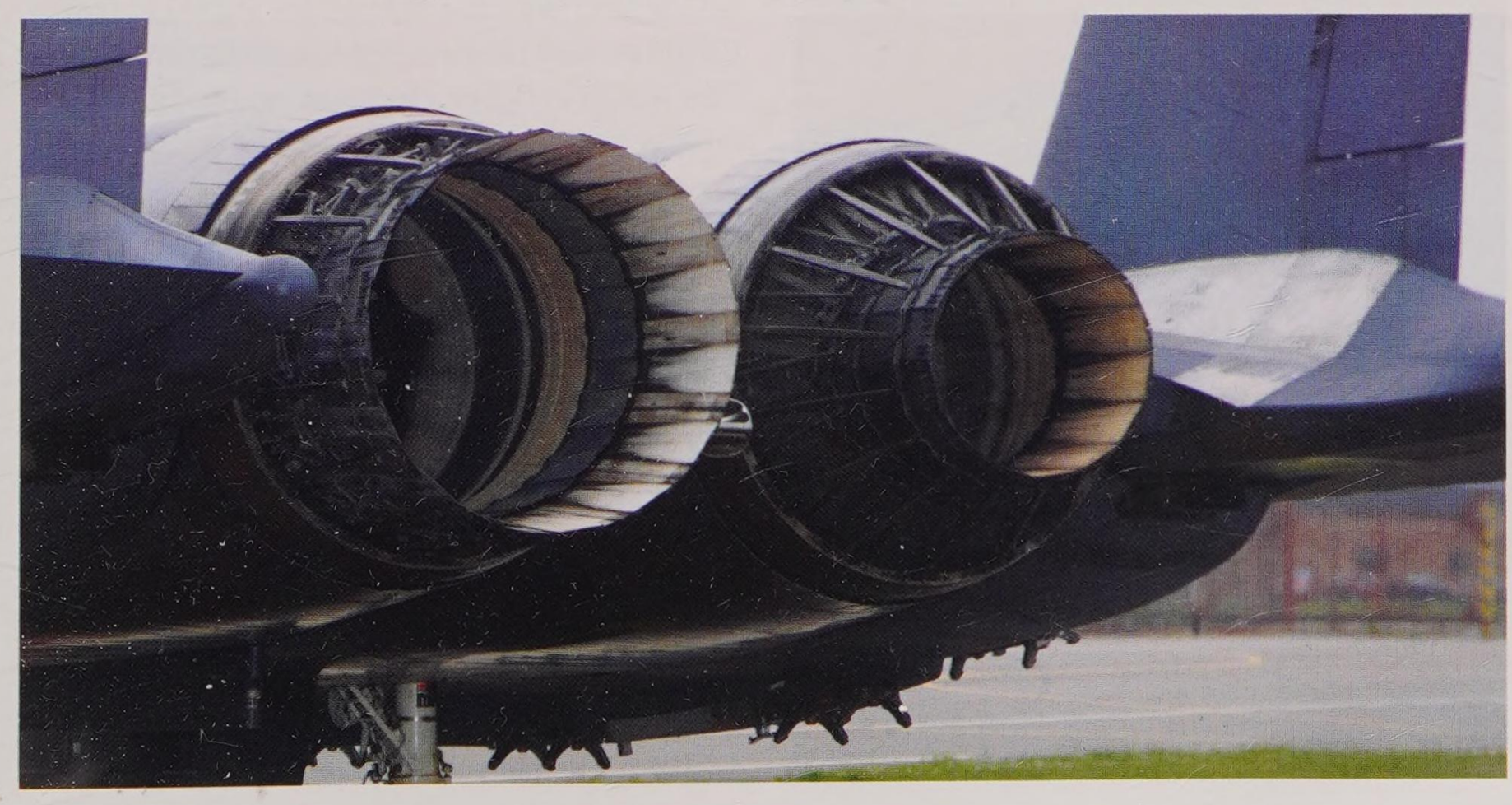
from 'MIL' to 'MAX'. The number of selectable afterburner segments is automatically reduced as the aircraft moves towards the upper left corner of the afterburner operating envelope.

During snap accelerations the first segment of the afterburner may, depending on flight condition, light at just above 'IDLE' rpm and the succeeding segments will light as speed approaches 'MIL' rpm. When 'MAX AB' is selected, FTIT will increase by as much as 50°C over MIL power FTIT.

The engine uses a light-off detector (LOD) to signal the IDEEC if a light-off occurs. The IDEEC then schedules the AFC fuel flow for the remaining segments. If the LOD does not sense a light-off or a blowout occurs, the IDEEC automatically resets the MFC to 'MIL', terminates afterburner fuel flow, and a check of the LOD is performed. If the LOD checks good, the IDEEC will automatically attempt up to three more relights. If the afterburner still fails to light, retarding the throttle to 'MIL' or below will reset the IDEEC and the system will operate normally when afterburner is reselected. If the LOD checks fail, the IDEEC will attempt one relight, bypassing the LOD, using tailpipe pressure to verify an afterburner light-off. Afterburner light-off may take longer and appear to hesitate if the LOD has failed. Afterburner is inhibited in the 'ENG CONTR OFF' mode.




**LEFT The Strike Eagle did away with the 'steam gauges' of the Eagle. This engine monitoring display gives the pilot all the information he needs regarding engine performance but takes up very little space doing it.** *(USAF)*



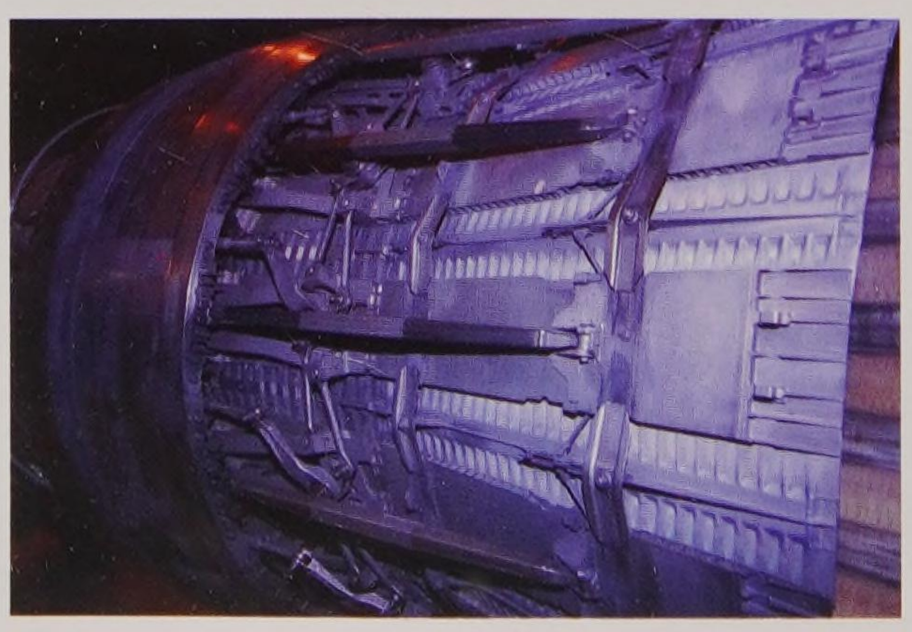
**LEFT The rear exhaust nozzles open and close to govern pressure in the afterburner chamber. Here, a pilot checks that each engine's nozzles and control modes are working.** *(Steve Davies/ FJPhotography.com)*

**RIGHT** Afterburner sections for PW-220s sit ready for inspection at the engine shop at RAF Lakenheath. *(Steve Davies/ FJPhotography.com)*

**FAR RIGHT** The afterburner section routes the turbine exhaust past a set of fuel rings that spray raw fuel into the airstream. The resultant ignition of the fuel creates the afterburner plume. *(Steve Davies/ FJPhotography.com)*

**RIGHT** The bright white of five of these afterburner sections indicates refurbishment by Lakenheath's engine shop, while the dirty cans have probably recently passed inspection for continued use. *(Steve Davies/ FJPhotography.com)*

**BELOW RIGHT** Hydraulic pressure controls the position of the engine exhaust nozzles, leading to a high pitch and brief squeal when the control rods actuate. Anyone who has watched a flight of F-15s land will have heard this distinctive sound as it is most audible when the F-15 engines are at low power settings. *(Steve Davies/ FJPhotography.com)*



## Variable-area exhaust nozzle

The engine has a convergent-divergent nozzle system that is continuously variable between minimum and maximum opening. The nozzle is positioned pneumatically by engine bleed air.

## Exhaust nozzle control

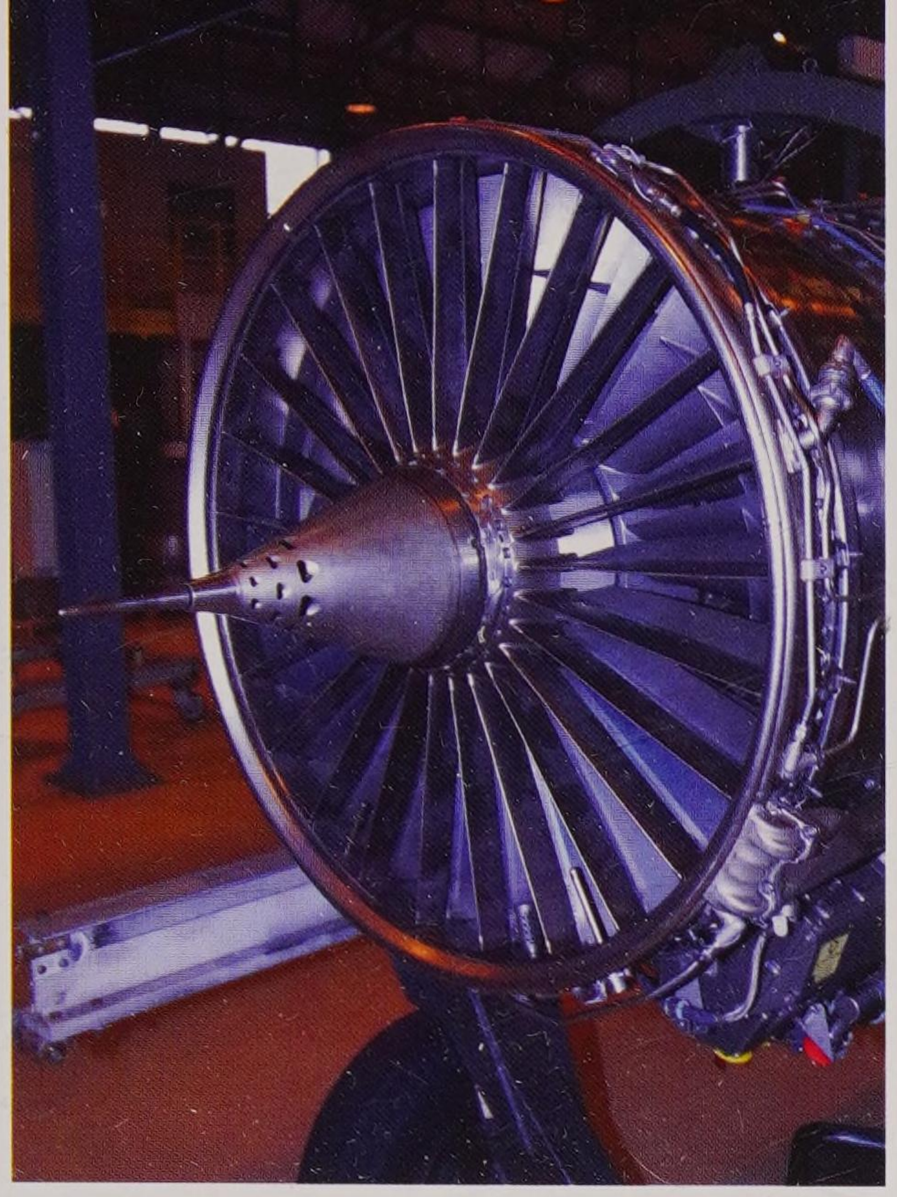
The exhaust nozzle is controlled by the throttle position and landing-gear handle position. With the gear handle down, throttle in 'IDLE' and the IDEEC on, the nozzle will be approximately 80–100% open. As the throttle is advanced, the nozzles close to near minimum area. With the landing gear handle up, the nozzle is near minimum area (10%) when the throttle is below 'MIL'.

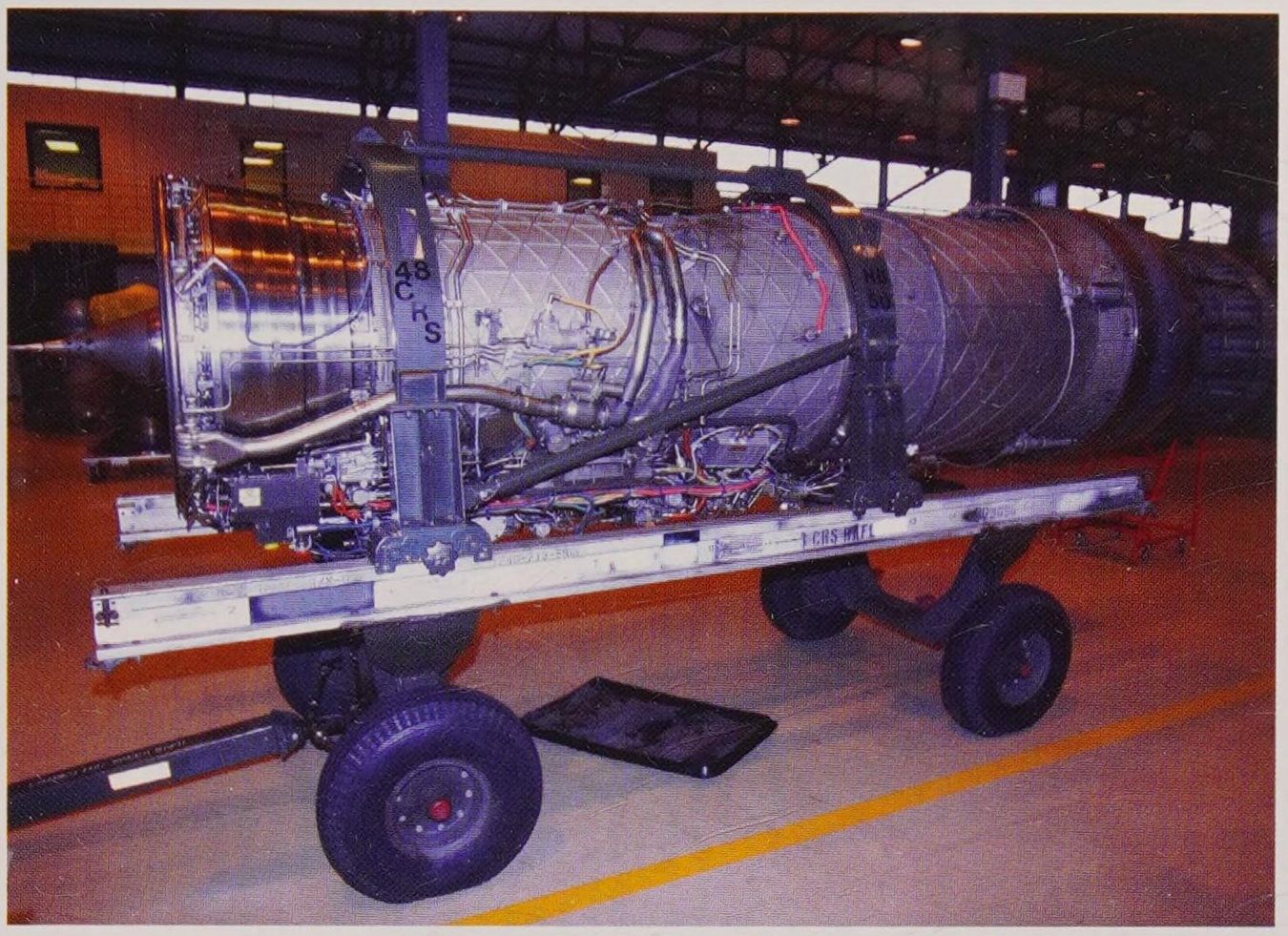
At subsonic speeds with the throttles at 'MIL', the nozzles will generally be less than 20% open; at supersonic speeds with the throttles at 'MIL', the nozzles can be as high as 45% open. As the throttle is advanced in the afterburner range, the nozzle will schedule further open to compensate for increasing afterburner fuel flow. With the IDEEC off, nozzle position will be closed to near minimum area (<5%) in flight or on the ground. This results in higher idle thrust and taxi speeds.

## Anti-ice system

The engine anti-ice system is comprised of the inlet ice detector and the engine anti-ice valve. The engine anti-ice valve and the inlet ice detector are functionally unrelated. The detector only senses engine inlet ice build-up and turns on the 'INLET ICE' caution. The engine heat switch, on the front cockpit environmental control system (ECS) panel, controls the engine anti-ice airflow to the engine nose cone and stationary inlet guide vanes and electrically heats the inlet pressure probe.

The IDEEC will automatically shut off the engine





**ABOVE LEFT The PW-229 is externally distinguishable from the PW-220 primarily by the extended sensor on the compressor section.** *(Steve Davies/FJPhotography.com)*

**ABOVE An additional identification feature is the crosshatch pattern on the engine casing (compare it to the vertical lines of the PW-220 afterburner section.** *(Steve Davies/FJPhotography.com)*

anti-ice when the altitude is above 30,000ft or the engine inlet temperature is above 15°C (60°F) or throttle is advanced beyond approximately mid-range, regardless of switch position.

## Asymmetric thrust departure prevention system (ATDPS)

With the higher thrust of the PW-229 engines, the ATDPS is designed to reduce the possibility of a directional departure due to asymmetric thrust at high calibrated airspeeds.

In response to an AB blowout or an 'ENG CONTR' caution, while in critical flight conditions (above 500kt calibrated airspeed – KCAS – while greater than Mach 1.1), the ATDPS drives both engines to SEC control. In SEC mode the thrust from both engines is equalised. After the aircraft exits the critical region, ATDPS automatically enables PRI operation of both engines.

Asymmetric thrust resulting from failures that do not cause an 'ENG CONTR' caution will not be protected by ATDPS. ATDPS provides protection for all store loadings except for three external tanks without CFTs.

## Fire warning and extinguishing

The fire warning and extinguishing system consists of three illuminating pushbutton switches, one fire extinguisher bottle, a discharge/test switch, fire sensors located in the engine and AMAD compartments, and various warning/caution lights. The system provides engine and AMAD fire warning, emergency engine and JFS shutdown, and selective fire extinguishing.

The extinguisher is a gaseous system which provides one-shot extinguishing capability. The gas is non-toxic and non-corrosive and will not damage aircraft components. Electrical power is required to operate the fire warning and extinguishing system. During JFS operation, before the emergency generator comes on the line, only the AMAD system is operative.

**BELOW Engine checks in the Hush House at Eglin AFB, Florida.** *(Steve Davies/FJPhotography.com)*

*Chapter Five*

# Flying the Eagle: the pilot's view

**With the assistance of Colonel (retired) Robert 'Scout' Winebrenner, in this chapter Colonel (retired) Doug 'Disco' Dildy describes a typical Eagle sortie from the late 1990s. Both men served in the US Air Force for 27 years, flying multiple tours in the F-15C, including combat hours over Iraq. Disco retired in 2001 with 1,400 Eagle hours, his last position being Vice Wing Commander of the 33rd Fighter Wing, Eglin AFB, Florida. Scout retired in 2005 as chief of tactical evaluation for USAFE, with more than 2,000 Eagle hours.**

**OPPOSITE With the star-spangled banner folded and tucked securely between the canopy and cockpit coaming, this F-15 pilot gathers his thoughts prior to a combat mission over Iraq in March 2003. The intensity of peacetime Eagle training sorties is intended to prepare pilots for the rigours of combat as realistically as possible.** *(USAF)*

**ABOVE The November 2005 reactivation of the 64th Aggressor Squadron at Nellis AFB saw the application of two-tone brown and blue camouflage schemes for the first time to the 'light grey' Eagle fleet.** *(Rob Tabor)*

## The mighty Eagle

The F-15C Eagle is a thoroughbred, a pure fighter designed specifically and exclusively to dominate the airspace in contention and, through the destruction of adversary aircraft, enable friendly air, ground and sea forces to accomplish their missions without interruption or interference. While its multi-role stablemates – its 'air-to-mud' cousin the F-15E Strike Eagle and the F-16 Fighting Falcon – can also engage in air-to-air combat, only the Eagle's replacement, the F-22 Raptor, can do it better.

'War is hell,' Civil War General W.T. Sherman is often quoted as saying, to which World War Two General G.S. Patton added 'and getting shot at is a real son-of-a-bitch'. Combat is intensely stressful, a tightly compressed experience when there are many distractions bombarding the brain, some of them with every intent to kill you. In order to function effectively in spite of these stressors, and accomplish our mission successfully, frequent, repeated and intense training is required on a regular recurring basis. In spite of all the wizardry and weaponry built into the 'Almighty Eagle', it always comes down to pilot proficiency and tactics, tactics, tactics.

This discussion will take you through a full-fledged training mission for a new, young wingman, fresh from pilot training and the Eagle 'schoolhouse'. As the squadron commander (which I was at one time), I will brief and lead this multi-task sortie that – depending on my wingman's performance – should result in me certifying him or her (for simplicity, we'll refer to a generic 'him' hereafter) as 'mission ready' and thereby welcomed into the family of our squadron and the larger fraternity of Eagle Drivers everywhere. In fact, the squadron 'Snacko' has laid on a 'roll call' this evening which will include his 'naming' ceremony (or

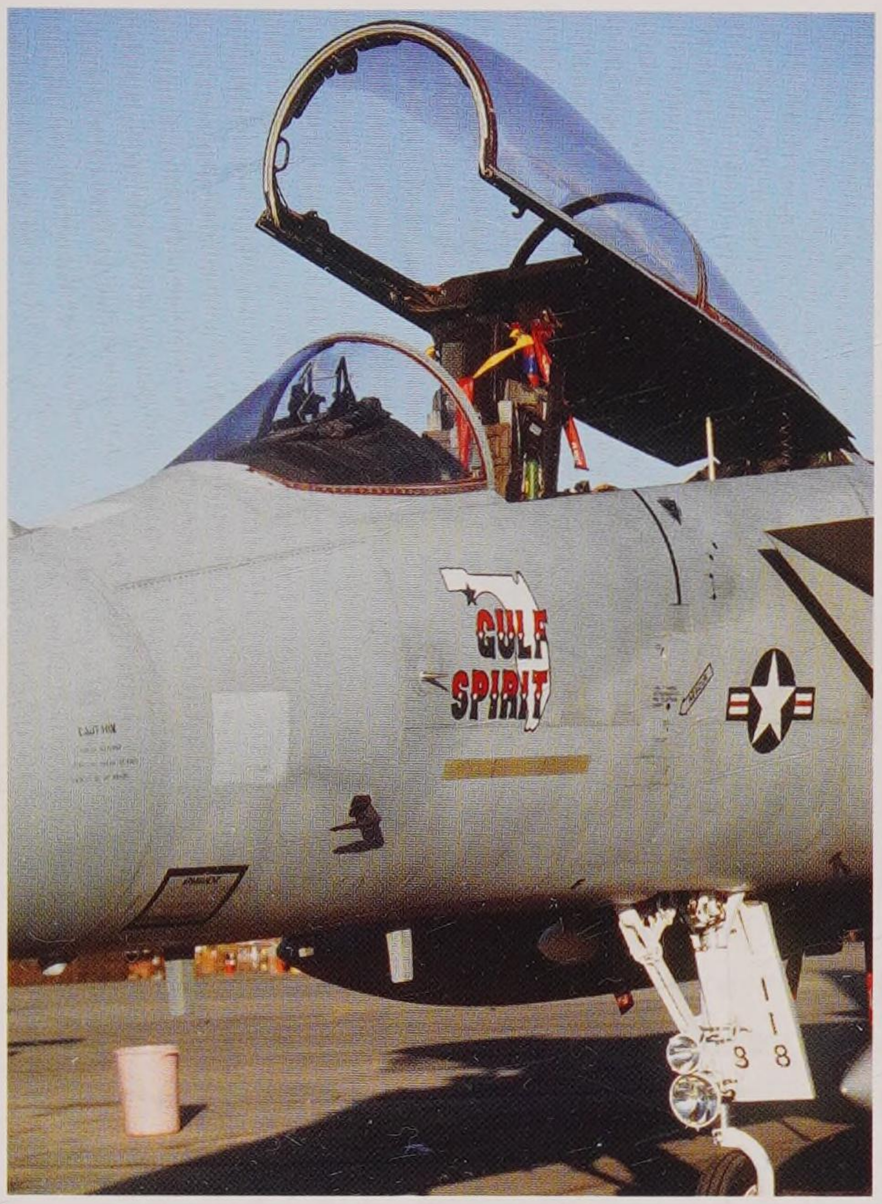
**RIGHT Two 18th Wing F-15Cs formate over the Pacific. The 'Wing King's Jet' (wing commander's aircraft) is 78-543. Aircraft 78-500 served with all three F-15C squadrons at Kadena and was on strength with the 67th (red tail) FS in 2006. Both are shown carrying AIM-120s and the KITS training pod.** *(USAF)*

otherwise he will be highly humiliated) where we will award him his tactical call-sign, the name by which he will hereafter be known in our unit and by others, especially in the air.

## Mission planning

No flight will ever go any better than the briefing, so we begin as we expect to execute: professionally and with precision. The brief starts two hours prior to take-off time, but by then I've already invested hours (the evening before or early that morning) planning and coordinating the specific mission elements. This mission will consist of a normal flight out to over-water supersonic airspace, a four-versus-four (4v4) dissimilar air combat training (DACT) offensive fighter sweep against F-16 Vipers (no one ever called the F-16 anything but 'Viper', except maybe the lawyers in the Pentagon who dictated its clumsy official nickname), air-to-air refuelling (AAR) off a KC-10 tanker, then three 1v1 basic fighter manoeuvre (BFM) engagements against 'Egg 02' (his temporary tac call-sign, as an unborn Eagle Driver, until his official naming – hopefully tonight) before returning to base (RTB).

The 4v4 DACT scenario is that we are the first daylight mission on Day 1 of a campaign against a rogue Middle Eastern nation, sweeping in ahead of 16 F-16s who will destroy a portion of their nuclear weapons development capability. Our adversaries are four Air National Guard (ANG) Vipers that will simulate enemy MiG-29 Fulcrums with their usual weapons suite. We will ingress from the west, driving to an inertial navigation system (INS) reference point near the centre of the airspace that represents the friendly F-16s' initial point (IP), a waypoint at which they will turn and fly directly to their target, a nuclear reactor on the city's outskirts. We are simulating ingressing four minutes ahead of the leading F-16CJ suppression of enemy air defences (SEAD) flight, who will neutralise the SAM threat, followed two minutes later by three four-ships of bombers, a minute apart. So we have to sweep in to the IP, kill all challengers, and then maintain supremacy of that airspace for ten minutes. The MiG-simulating Vipers will come from a home base to the east and, after being 'killed' will regenerate by returning to that point, 'tagging base' and then coming at us again simulating a newly launched adversary.




**LEFT The 33rd TFW's flagship was christened 'Gulf Spirit' after the Gulf of Mexico. The 58th TFS embodied that spirit and did very well during Operation Desert Storm for a number of reasons: leadership, the vast experience and talent of its pilots, recent experience training with aggressors in the US, and just a little bit of luck.** *(USAF)*

## Briefing

Five minutes before brief time, I'm expecting all flight members to be in the briefing room, all other concerns left outside. When I close the door one minute prior, rank no longer applies – it doesn't matter if God is No3 or No4, He has no speaking part unless I ask Him a question or He asks permission to ask one Himself. Today, Eagle 03 is 'Scout' (Lieutenant Colonel Bob Winebrenner, a long-time friend – we had our first tour in Eagles together at Bitburg – and an extensively experienced F-15 instructor pilot who's spending a week away from his HQ duties to maintain his proficiency in the Eagle).

Beginning with a 'nuclear' time hack we synchronise more than just our watches (and later our jets' clocks) and set the tone for the precision and coherence with which we will execute this mission. I quickly provide a cursory overview of the mission flow (4v4 DACT, AAR, BFM, RTB) followed by the mandatory 'motherhood': flight line-up and call-signs including the AWACS (the E-3 Sentry that will 'control' our mission) and tanker, weather/NOTAMs, emergency of

the day, ground operations, afterburner take-off, tactical departure, en route to airspace and back, refuelling details, handling emergencies, and the training rules (TRs). To save time for the important mission elements, most of these are succinctly mentioned as 'standard', since they are described in wing operations instructions, but the TRs are addressed in some detail, especially those designed to prevent us from having a mid-air collision – historically the greatest single cause of Eagles lost and pilots killed.

Then the DACT scenario is explained and the 'tactical administrivia' is covered: training objectives, today's adversaries and their capabilities, AWACS communications ('comm'), radar and visual lookout, rules of engagement (ROE – in this case it's 'weapons free' until we get to the IP/'bullseye', then it's positive identification (PID) based on electronic sensors or visual identification (VID), 'bullseye' location and codename ('Omaha'), shot criteria (two shots prior to first merge, single-shot thereafter, no 'reloads'), other codewords, timing, and egress plan. Then we – like the devil – get into the details: we'll ingress line-abreast ('wall of Eagles') with lead and 03 on the inside, 02 and 04 on the flanks, just beneath the contrail layer, at min-afterburner close to Mach. Radar search responsibilities are standard – I'll look in the area I anticipate the adversaries to show up in (from the contrail level down), with 03 looking opposite (from the ground up) and our wingmen taking the opposite of their element leads. All contact references will be off of bullseye, we'll assign target groups on a side-to-side/lead-trail basis (called 'sorting') as soon as they 'breakout', and we'll 'action' (execute our tactic) around 20 miles.

The tactic will be decided based on the adversary's own deployment. If they stay together – 'hey diddle, diddle, they're right up the middle' – we'll execute a 'bracket' (or 'pincer') to get an element attacking from each flank. If they 'lean' to one side trying to outflank us to get at the strikers, we'll 'single-side offset' to cut them off and intercept them well before they can target our Falcon brothers coming in behind us. Once the enemy's first wave is eliminated, we'll hustle over to 'bullseye' and establish a counter-rotating CAP (combat air patrol), with one element looking 'hot' (towards the adversary home base/regeneration point) at all times, committing out of the CAP to engage the approaching threat (second wave) before they reach 20 miles from the IP.

Any questions? Once answered, we split up for a quick element brief covering how we'll handle various tactical situations as a two-ship, and then brief the BFM engagements – one offensive, one defensive, and one neutral set-up – and associated shoot and kill/'knock-it-off' criteria. At the 50-minute point we adjourn to Aircrew Flight Equipment (AFE – a kind of aerial gladiator's locker room) and get into our g-suits, combat vests and parachute harnesses, and grab our helmets and 'brain bags', then stop by 'the vault' (the secure weapons shop) to pick up our digital data transfer modules (DTMs) that contain all the comm and nav info, etc, before rendezvousing at the squadron ops desk for our aircraft assignments and final airfield/weather status briefing one hour before take-off.

## Step to the jet

'Awesome!' is the word that leaps to mind the first time a new Eagle Driver first walks out to the F-15. The Eagle is large for a fighter and it is immense, even imposing, as a dogfighter, standing tall and proud, the long tapered nose pointing purposefully into the air. Approaching the jet the aircraft's crew chief comes to attention and salutes. Returning it, I am handed the maintenance book (called AFTO 781) and the crew chief begins to brief me on the status of his jet and about any particular subsystem that has had a problem recently. Thanking him, I begin my 'walk-around' – the visual inspection of the jet, its missiles and external tanks – while the crew chief mounts the ladder to place my helmet on the canopy rail and my 'brain bag' in the map case.

Moving around the nose, I check the pitot tubes and AOA (angle of attack) probes and ensure that the forward panels covering the numerous radar components are securely locked down. Rounding the nose, behind which resides the APG-63's 3ft diameter planar array radar antenna, I give it a shove to be sure the radome is latched shut, before moving down the right side and diving below the belly to open the gun hatch and ensure that 'rounds limiter'

is set to be sure that none of the 940 20mm bullets actually shoot when I pull the trigger on practice gun shots. Under the right wing root, beneath the Vulcan's breech, a hatch is opened and I check to be sure the gun safing pin and cam holdback tool are inserted, further ensuring that the gun is safe and won't actually fire when the trigger is squeezed.

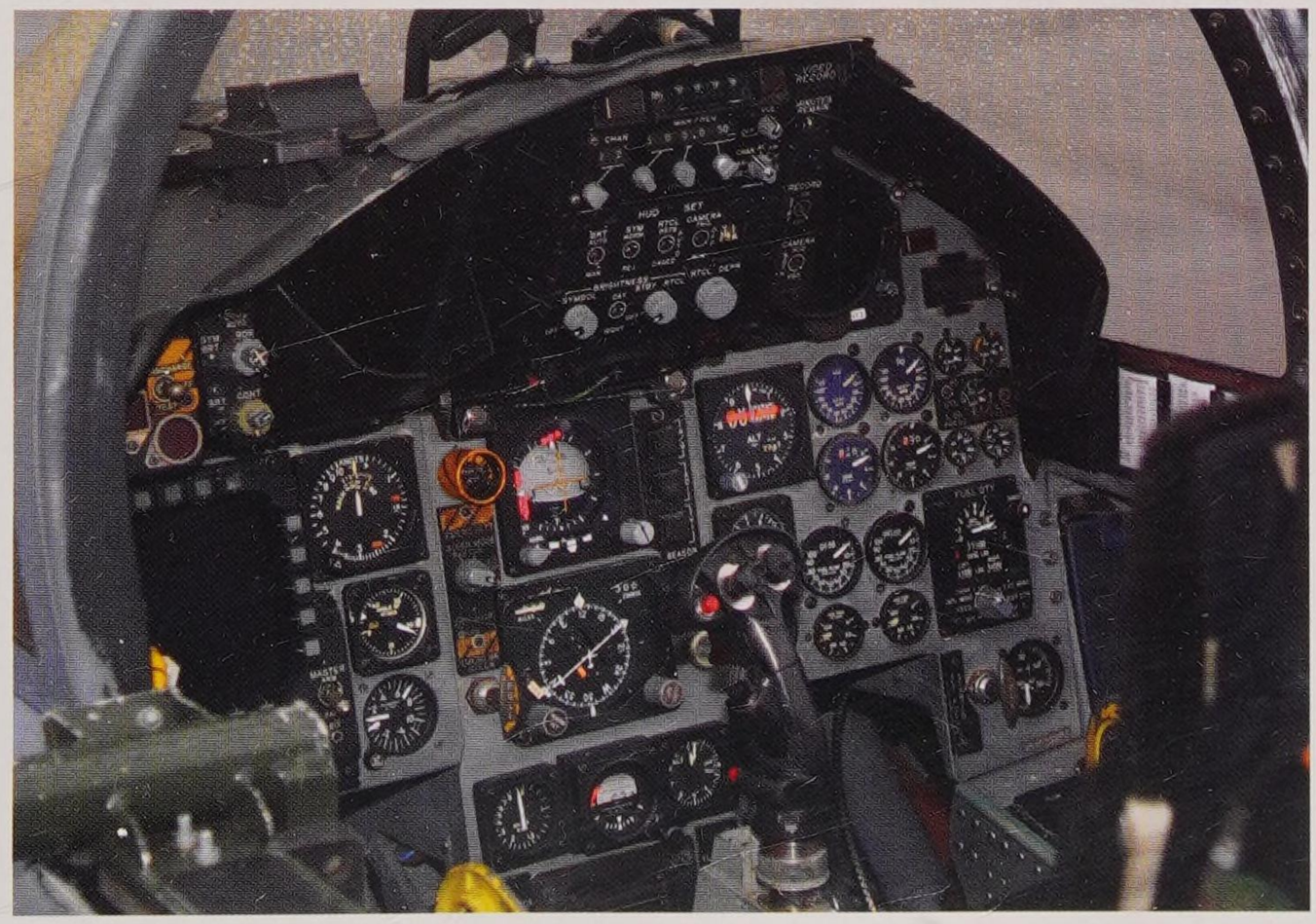
On the right wing pylon rail, I check the air combat manoeuvring instrumentation (ACMI) pod – an AIM-9-shaped pod that continuously transmits all my aircraft's data, including 'shot parameters' to the huge server in the ACMI debrief facility, allowing us to accurately reconstruct each engagement.

Around the right wingtip and back to the tail, I examine the flight control surfaces for any deformations or abnormalities, and standing between the tails I play a bit with the moveable nozzle's 'leaves', ensuring there is no binding and that they are ready to do their job in giving the Eagle its *umph*! Rounding the left stabiliser (stab), I inspect the same things on the other side, swing round the left wing and check the AIM-9 practice training missile (PTM) mounted to the left wing pylon rail. Removing the yellow rubber seeker-cover I check the missile's little 'eyeball' for defects before moving down the body of the missile, checking that the argon bottle quantity (argon cools the missile's seeker, enabling it to discriminate lower spectrum heat sources) is 'in the green', that the PTM is securely mounted on the rail, and that the umbilical is attached – the inspection of a PTM varies little from the inspection of a real missile.

My crew chief awaits my arrival topside by standing on the left intake. Atop the ladder I am easily 12ft off the ground, and, swinging one leg over the rail and into the cockpit, I 'mount' the beast, dropping down into the saddle of the ACES II ejection seat, and with the crew chief's assistance buckle the Koch (pronounced 'coke') fittings of my harness into the risers of the parachute that's in the headrest of the ACES II. I clip the buckles of the survival kit, mounted in the seat bottom beneath the cushion, to the sides of my harness, connect the hose from my g-suit into the receptacle in the left console, and on the right side snap the oxygen and communications assembly into place on my chest. Connecting the oxygen hose and communications cord of my helmet, I pull it on and tell the crew chief I'm ready.

**ABOVE Arriving at the jet, the first order of the day is to greet the crew chief and check the aircraft forms. This paperwork is important, as it will give a potted history of the aircraft's overall health and flag up any recurring issues of which the pilot needed to be aware.** *(Steve Davies/FJPhotography.com)*

There are a lot of switches to check before we start engines, mostly making sure that, except for the engine electronic control (EEC) switches, they are all off, so that any electrical surges associated with the generators coming on line do not damage any of the subsystem components. We switch the JFS (jet fuel starter) switch to 'ON' and pull the JFS T-handle. It discharges an accumulator that spins up the little JFS turbine located between the engines.



**BELOW The F-15C MSIP cockpit is roomy and generally well laid out. Note the HOTAS buttons on the stick grip.** *(Steve Davies/FJPhotography.com)*

**ABOVE The introduction of a data transfer module (DTM) has made life much simpler for the Eagle Driver. Whereas in the past he had to manually program all of the steer points for a given sortie each time he entered the cockpit, now he could allow a computer to take care of all of this. Now he simply took his DTC from mission planning, slapped it into the receptacle in the cockpit and then waited for the CC to extract all the data. Meanwhile he could get on with his other cockpit tasks.** *(Steve Davies/ FJPhotography.com)*

The JFS starting makes a distinctive wailing noise, and when that rising sound levels off it's ready to crank an engine.

The start levers for the engines are located on the front of the throttles, beneath the HOTAS switches on the throttle grips, and are called 'fingerlifts' – pulling one up engages the JFS to that engine and will spin it up to starting rpm, usually 18%. At that point the throttle is moved forward, 'over the horn', to 'IDLE' and the engine instruments (and fire warnings) are monitored for a normal and proper engine start. The crescendo of JFS tells me that it has successfully disengaged and is now ready to crank the other engine.

## HOTAS

Bringing all the necessary switches and buttons on the throttles and stick immediately under the finger or thumb meant that there was no requirement to look down into the cockpit. This idea – hands-on throttle and stick (HOTAS) – became a reality in the Eagle.

Comprising a collection of switches and buttons, HOTAS controls the Eagle's radar, weapons systems and self-defence counter munitions dispensers (CMDs). The controlling switch is the weapons selection switch, located under the left thumb (on the inboard side of the No 2 throttle), below the microphone and speed brake switches. There are three settings: medium-range missile (MRM), which selects an AIM-7 or AIM-120 missile and drives the radar into long-range search; short-range missile (SRM), which selects an AIM-9 and drives the radar into short-range search; and GUN, which selects the M61A1 gun and puts the radar into auto-guns mode if there is no current radar lock.

On the front facia of the inboard (No 2) throttle under the left middle finger is the target designator control, a rounded, pressure-sensitive device used to manually control the acquisition symbols on the radar and slew the auto-guns' search volume in GUN. Beside it is the interrogate IFFs button (all modes whether in search or track) and, in SRM, the AIM-9 Sidewinder boresight.

The outboard (No 1) throttle carries the gun sight reticule stiffen under the left ring finger for short-range, no-lock-on 'snapshots', and the radar antenna elevation rotary wheel under the pinkie finger. The CMD activation switch was added later on the outboard side of the throttle, to be hit by the edge of the hand 'karate-style' whenever chaff and flares were needed to spoil an enemy shot.

On the stick, the primary switch – the auto-acquisition switch – is under the right thumb. No matter which search mode is employed (no lock-on), pushing forward once selects Super Search (SS) and twice gives you Boresight (BST) to lock up a target visible in the HUD. Pulling it back sends the radar into vertical scan (VS) and pushing down on it sends the radar into return to search (RTS) mode, giving it back to the search mode commanded by the weapons select switch (MRM, SRM or GUN). When the radar is off and the aircraft is air-to-air-refuelling (AAR) this switch releases the boom from the AAR receptacle.

On the forward side of the stick is the nose-wheel steering button that, on the ground, engages or disengages the nose-wheel steering. But when the gear is up and SRM is selected, it uncages the AIM-9L/M seeker head to confirm a 'self-track' before shooting. At the top of the stick are the trim button, gun trigger and weapons release 'pickle' button.

**LEFT** **Engines running, canopy closed and radios tuned awaiting the call from lead to taxi, the Eagle pilot is zoned in for the mock air combat that lies ahead. Heads down attending to last-minute systems set-up, this will be his last respite from pressure and stress from some hours to come.** *(Steve Davies/ FJPhotography.com)*

Once the engines are running at idle, the JFS shuts itself off automatically and I lower the canopy to check ECS (environmental control system) airflow, cycle the EEC switches to exercise the nozzles and start setting switches for flight. Designed at the outset as a single-seat fighter, the pilot's workload is reduced to the minimum possible by automating almost all the aircraft's subsystems so the pilot can concentrate on flying the jet and fighting the enemy. Hence most switches have three positions: 'OFF', 'ON/AUTO', and 'MANUAL/RESET'. Naturally it's a quick and easy process to go around the cockpit from left to right and move all the switches to the 'AUTO' position. 'AUTO' engages that particular subsystem's own little computer to program its activities, relieving the pilot of any need to do so. Additionally, McAir has arranged the subsystem controls with those used in flight on the left (your throttle hand), while those we use on the ground are on the right. It is inconvenient in the midst of a furball to take your right hand off the stick to flick a switch in the cockpit, so the radio frequencies, IFF mode/code settings, radar controls, AAR slipway door switch, etc, are on the left console. Correspondingly those items that require manipulation on the ground – starting JFS/engines, the oxygen system, internal countermeasures set (ICS) and programming the INS – are located on the right console.

While waiting for the INS to align I check the radar's built-in test (BIT) features to ensure it will work in all the high PRF (pulse repetition frequency), medium PRF and interleaved modes, and that the tracking data will be stable when locked on.

While the radar finishes running its BITs and the INS completes its alignment, I check the flight controls and set the flaps to 'DOWN'. The most important thing is to be sure that the flight controls are connected properly and that the control augmentation system (CAS) works as designed. (One of the few flaws in the Eagle is the opportunity for a mechanic to connect the linkages of the flight controls backwards; this causes the flight controls to work opposite to the stick input, which has resulted in the loss of at least three F-15s and the lives of two Eagle Drivers.) The CAS is an electronic flight control override that, through the sensor unit mounted between the control stick and stick grip, provides precise control deflections by sensing the amount of pressure the pilot is demanding. This revolutionary system was the genesis of the F-16's fly-by-wire system.

## Ground ops

Within 15 minutes all systems are up to speed and all checks complete: it's time to taxi out for take-off. At the appointed time, I press my left thumb rearwards on the microphone button, engaging the auxiliary radio: 'Eagle 01, check.'

'Twoop.' 'Threep.' 'Fourp.'

We're all ready – thumbing forward to the main UHF radio, I call, 'Ground, Eagle 01 taxi with four.'

**RIGHT Crew chiefs marshal out two 9th TFS 'Iron Knights' F-15As for a training sortie at Holloman AFB, New Mexico. Aircraft 77-069 – 'the Love Machine' (any aircraft with the consecutive numbers '6' and '9' in its serial) – went from the 49th TFW to the 405th TTW in 1986, thence to the 122nd FS, Louisiana ANG, in 1992. F-15A 77-073 followed a similar route but wound up with the 123rd FS, Oregon ANG.** *(USAF)*

Ground control clears us to taxi to the runway and I push the throttles forward gingerly, so as not to sweep away everything behind me with the P&W F100's cyclone-like thrust. Turning on to the taxi lane, I watch with satisfaction as the other three jets pull out of their parking spots and fall into line behind me.

At the 'last chance' (also known as the end of runway or EOR) area, maintenance personnel inspect our jets for any leaks, tyre cuts or other abnormalities, arm the PTMs and remove their pins and covers, and watch while we perform another flight control check. Once they are clear the radar is turned on, ejection seat armed, take-off trim checked, and we're ready to go fly.

**BELOW At the end of runway area (EOR) a pilot prepares to show his hands to the ground crew – a precautionary measure that means he won't bump the stick with his hand. The very powerful flight control surfaces could fatally injure a member of the EOR crew as they scamper around the jet checking for buttoned up panels and leaks. This aircraft has two Su-22 kill markings.** *(Randall Haskin via Steve Davies)*

## Take-off

I've coordinated with air traffic control (ATC) for a comm-out launch, and once all four of us have passed EOR inspection, the landing/taxi lights are flicked on up the line – four, three, two, me. The tower controller is paying attention and, after a visiting trainer makes a practice approach, calls, 'Eagle 01 flight, cleared for take-off, winds 0-9-0° at 10kt.'

Pushing the throttles forward gingerly, I lead us out on to the runway, lining up in the centre of the upwind side. Looking over my shoulder I see Eagle 02 pull up alongside me, offset to the other side of the centreline. Eagle 03 squeezes in beyond him – I can see Scout's helmet across the back of 02's fuselage – and 04 lines up in the slot behind my element. Scout gets a nod ('Ready') from 04, passes it to 02, who relays it to me. I stick two fingers into the air and give them a twirl: 'Run 'em up!'

**LEFT** **Engines run up and ready for brake release, MOGAR F-15A 77-118 prepares to launch on an OSW sortie. An A-model unable to take off with a full external load must leave something behind. In this case the 110th FS elected to go with three 'bags of gas', two AIM-7Ms, two AIM-120s and a pair of AIM-9Ms for maximum flexibility, if not maximum firepower.** *(USAF)*

Jamming my boots on the brakes and shoving the throttles forward until I get 80% rpm, eight F100s roaring behind me, I check the stack of paired engine instruments – no need to read the numbers; if the needles are steady and parallel they're good to go. Checking 02, he nods 'Ready' and I place the back of my skull against the cranium-rest, hesitate, then nod sharply forward as I release brakes and smoothly shove the throttles forward 'over the hump' into AB (afterburner). This is done slowly enough to feel each stage of the AB light off, and, smiling at the exhilarating feel of the progressive kicks in my backside, my eyes glance down to the nozzle gauges and see the needles swing open in three jumps. 02's got two more stages of AB if he needs them, but a quick check tells me he's wired into position. The sidelines become a streaking blur and the airspeed read-out on the HUD keeps rolling faster and faster. At 120kt I give a quick pulse on the stick to get the nose up, the main gear to lift off, and, checking 02's position, I raise the gear and flap levers.

This is a tactical departure so as soon as we pass the far end of the runway I flick the stick away from 02 – and seeing this, he does the same away from me – and we aggressively pull apart 45°, reverse bank, and pull back to the runway heading. By the time we roll out – line abreast 6,000ft apart – we're hitting 300kt, throttles out of AB. At 350kt, still skimming low to mask ourselves from man-portable air defence missiles (MANPADs – Stingers and SA-7/14s), we pull up into a climb as I note with satisfaction that my RWR (radar warning receiver, pronounced 'raw') has announced that Scout's element is tied to ours. We are now in a 'container' (some would call it a 'box') formation for the climb and cruise to the airspace.

**BELOW** **The reduction of Stateside and USAFE Eagle units resulted in even Kadena's 18th Wing sharing the load of patrolling the no-fly zones. Here a fully loaded 67th FS 'Fighting Cocks' F-15C blasts into the air from PSAB, Saudi Arabia.** *(USAF)*

**LEFT Sometimes it was hard to believe they were paying us to do this – to fly (and fight in) the most awesome air superiority fighter known to man. Loaded with 'wall to wall missiles', mounting an internal gun and able to sustain its maximum performance gs, the F-15 was the ultimate air-to-air killing machine of the 20th century. Here 77-117, of the 49th TFW's 8th TFS 'Black Sheep', shows off its armament suite high over the mountains and desert of New Mexico. This aircraft was destroyed in a crash on 12 June 1993 when on strength with the 122nd FS Louisiana ANG. The pilot ejected safely.** *(USAF)*

## En route

Cruising out to the airspace, I 'porpoise' my jet (pulse the stick to make the nose bob up and down), signalling 02 to collapse in for his weapons checks. He's paying attention and comes swooping in from the side, settling in behind me to make sure his PTM is slaving, tracking, and boresighting correctly and that all his radar auto-acquisition ('auto-acq') modes work properly, checks his ABs and goes scooting past for me to do the same. Using his jet as a target, I 'play the piccolo' on the HOTAS to get various auto-acq lock-ons: left hand thumbing to SRM (short-range missile) to see on the HUD the AIM-9's seeker-circle swoop from boresight (straight ahead) to the target designator (TD) container, right ring-finger pushing the 'uncage' button on the stick grip, to see the seeker-circle swirl around the target's exhausts while I get the familiar self-track tone in my headset; then use my left index

**LEFT These aircraft are Holloman A-models. F-15 77-099 carries an interesting mix of live AIM-7s (yellow bands on the missile indicate a live warhead, brown bands a live rocket motor) and inert AIM-9s (blue bands or, as in this case, a blue missile body, indicate a captive-carry inert missile). After serving in all three 49th TFW squadrons between 1979 and 1991, this jet was MSIP-modified and sent to the 32nd FS at Soesterberg AB, Netherlands. In 2006 it was with the 101st FS, 102nd FW, Otis ANGB, Massachusetts.** *(USAF)*

finger to hold down the boresight button to bring the seeker back to HUD centre. Breaking lock, I swing the nose to 02's tailpipes, get the growling tone, uncage and see that Sidewinder self-tracks without the radar's assist. Behind us Scout and his wingman are doing the same. Checking 'blowers' (ABs) again, I close on 02 and pass him on his right side, resuming the lead and porpoising my jet again.

This time it's the signal for the 'cons check' and 02 pulls up and away to the left, soaring upwards into the deep indigo blue. Returning to my navigation (nav) and coordination duties, soon enough I hear Scout call 'marking' and look up and left – sure enough, thick fluffy tubes of white condensation (cons) stream from 02's exhausts. He calls succinctly 'Three-nine-oh', meaning the contrail level begins at flight level (FL) 390, going up to who cares. So I'll plan our sweep and shots to be from the high 30s.

As we approach the airspace, we check in with the controlling agency, are cleared in and to Sentry 6-9's frequency. A quick radio check there confirms radar contact with us and that the 'targets for today' are also entering the airspace from the other side. With a call, we switch the radios to the tactical net ('Have Quick') and I call 'Eagles, fence in.' My left hand moves around the cockpit, fingertips turning on all tactical equipment and flipping the Master Arm switch to 'ARM' and the digital video recorder (DVR) to 'RUN'.

Once confirmed that we're in the airspace I call for 'g-check left', and we execute sharp, hard 90° g-awareness turns to warm up our bodies to the rapid onset of gs that the Eagle can generate, tensing our abdominal muscles and thighs – much like giving yourself a Heimlich – straining against the blood-draining effects of 3–4gs and feeling the commensurate gut-tightening hardness of our g-suits. Some of my attention is on 02, making sure he flies crisp, hard turns, getting warmed up properly – after mid-airs, g-induced loss of consciousness (GLOC) is the next greatest cause of Eagle accidents. This can be an unforgivingly deadly serious business.

'G-check right,' and we repeat the 90° hard turn, this time at 5-6gs adding min-AB to minimise airspeed loss, rolling out line abreast with 'Omaha' off the nose about 30 miles away. Scout and 04 have done the same, only in the opposite direction, so when I look right I see them line-abreast about four to five miles away. When I look left I see 02 is line abreast, climbing slightly to get some additional potential energy – he's probably going to need it.

'Vipers are ready to play,' Sentry announces.

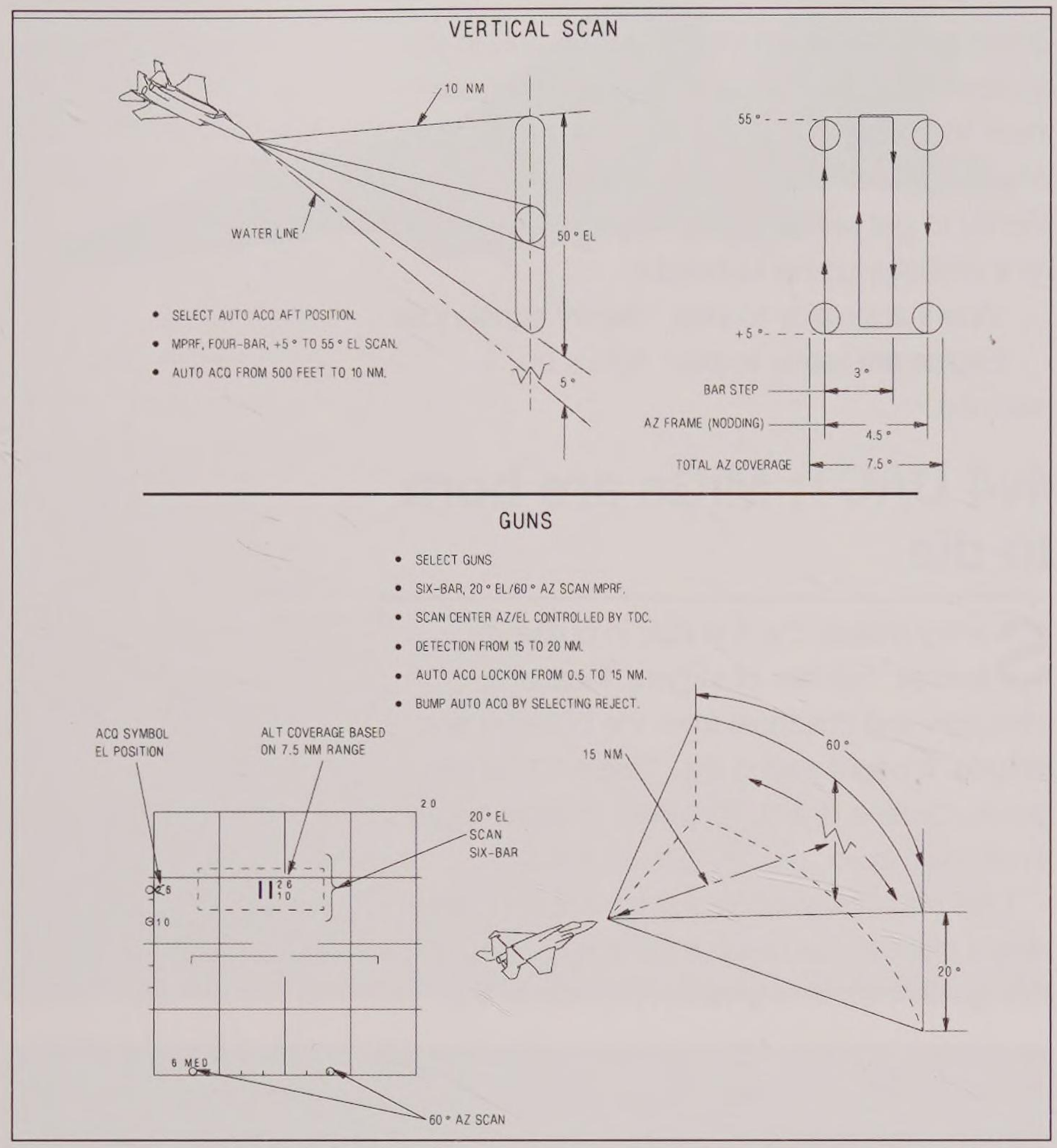
'Eagles are ready to play; fight's on,' I respond.

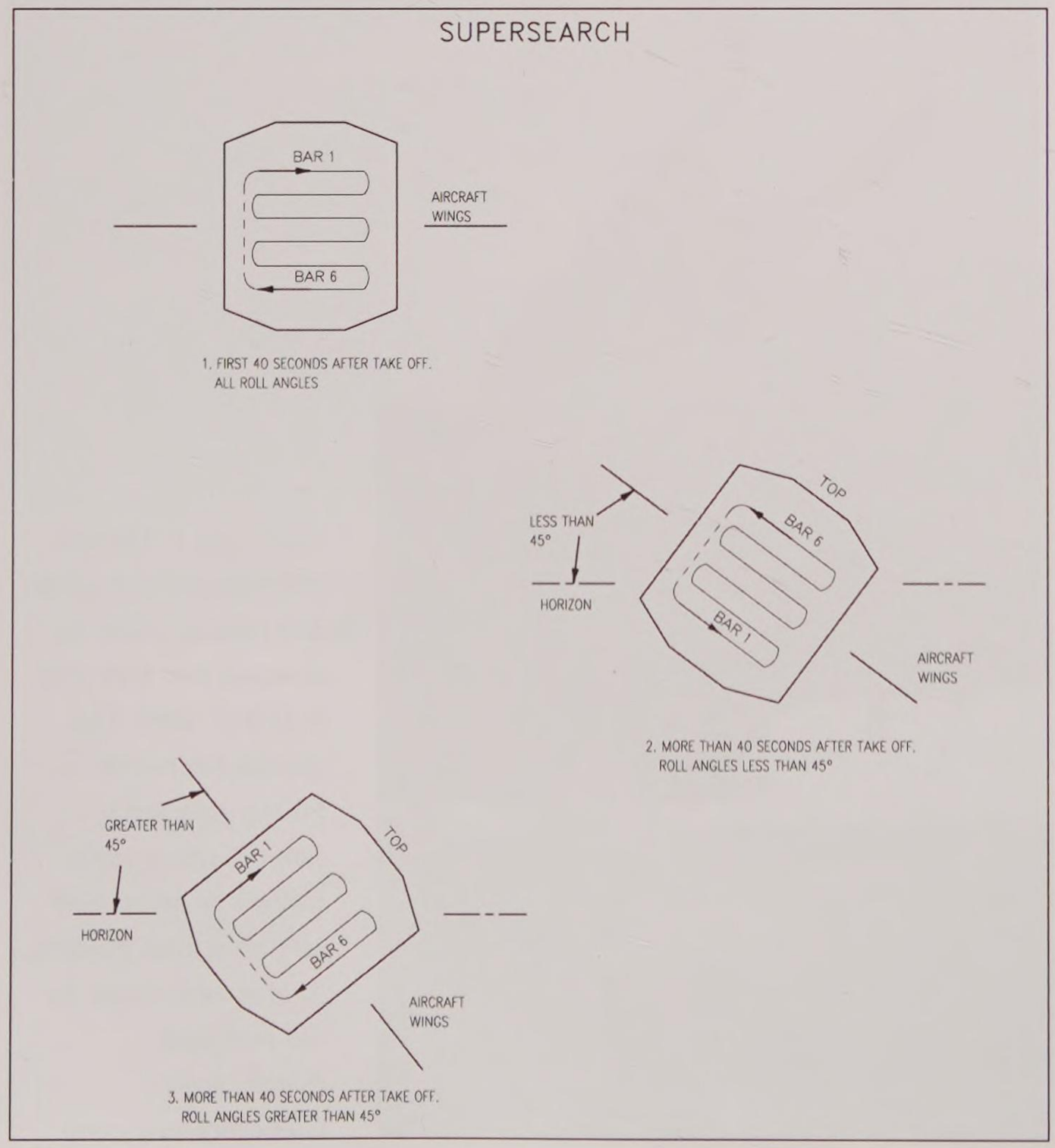
## 4v4 DACT: MiGs are born to die

Sentry makes the first call, in bullseye format: number of targets, location (direction and distance) from the bullseye and altitude. It might sound like, 'Eagle 01, single group, Omaha 0-9-0, 30 miles, multiple bogeys, three-eight-zero.'

I tap min-AB, starting a shallow climb, and take a peek at the radar; I see a tight, bright little green blob on my radar, centred in the

**LEFT The F-15C (86-0156) flown by Captain Jeff Hwang when he downed two MiG-29s in March 1999. The double-kill markings on the side are a reminder that while today's mission may be peacetime training, tomorrow's could be the real deal.** *(Steve Davies/ FJPhotography.com)*




**LEFT Vertical scan and guns auto acquisition modes sweep the radar beam in predefined patterns and automatically lock on to the first return within ten nautical miles.** *(USAF)*

top half of the VSD. Looking out ahead and high, I check to see if any of them have left any contrails – 'a peek is worth a thousand sweeps' – but, no, the sky is clear and blue. Using my left index finger I position the target designator control (TDC) symbol – a pair of vertical bars that look like American football goalposts – over the blob.

'Eagle, contacts there,' I call back.

A litany of contact calls continue from Sentry as we push through 480kt; at 0.98 Mach, outside my form-fit helmet the airstream is roaring across my huge bubble canopy. Checking to the left, 02's continued to stack high as we've climbed, his jet intermittently puffing out twin contrail streams as he's inadvertently tapping the con-layer. Before I can press the mike button, Scout calls, 'Two, you're marking.' That will be a debrief item. Immediately, 02 pushes down, descending to nearly my level.

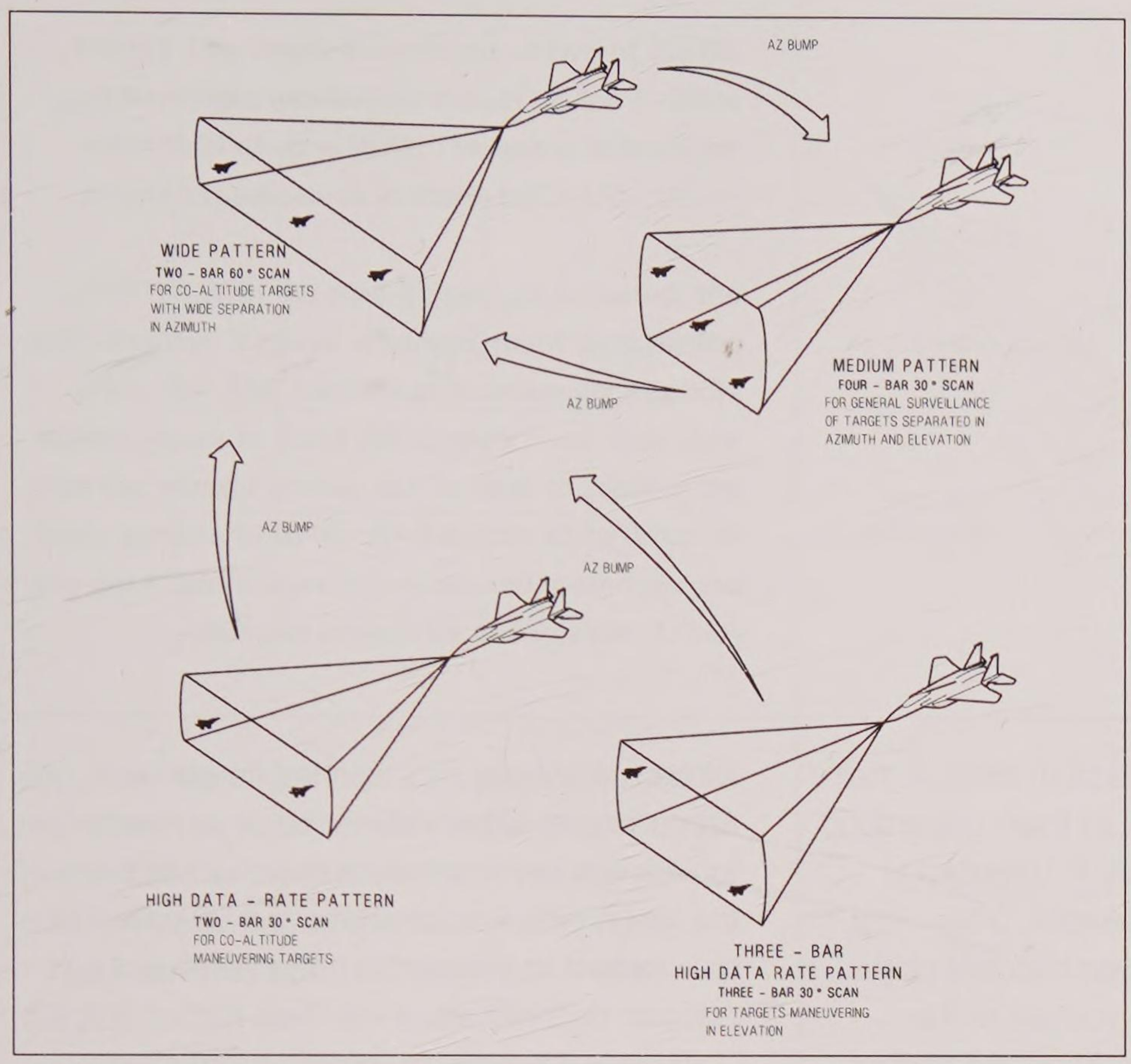
If the Vipers see his mark, it will be an arrow-like finger pointing where we're headed – I've got to change that. 'Eagles, check 30 left.'

Simultaneously all four F-15s bank and turn 30° to the left, now heading 060°, off-setting to the north. Our radar look is now skewed, but still workable, and at least we won't be where 02's cons indicated we're headed.

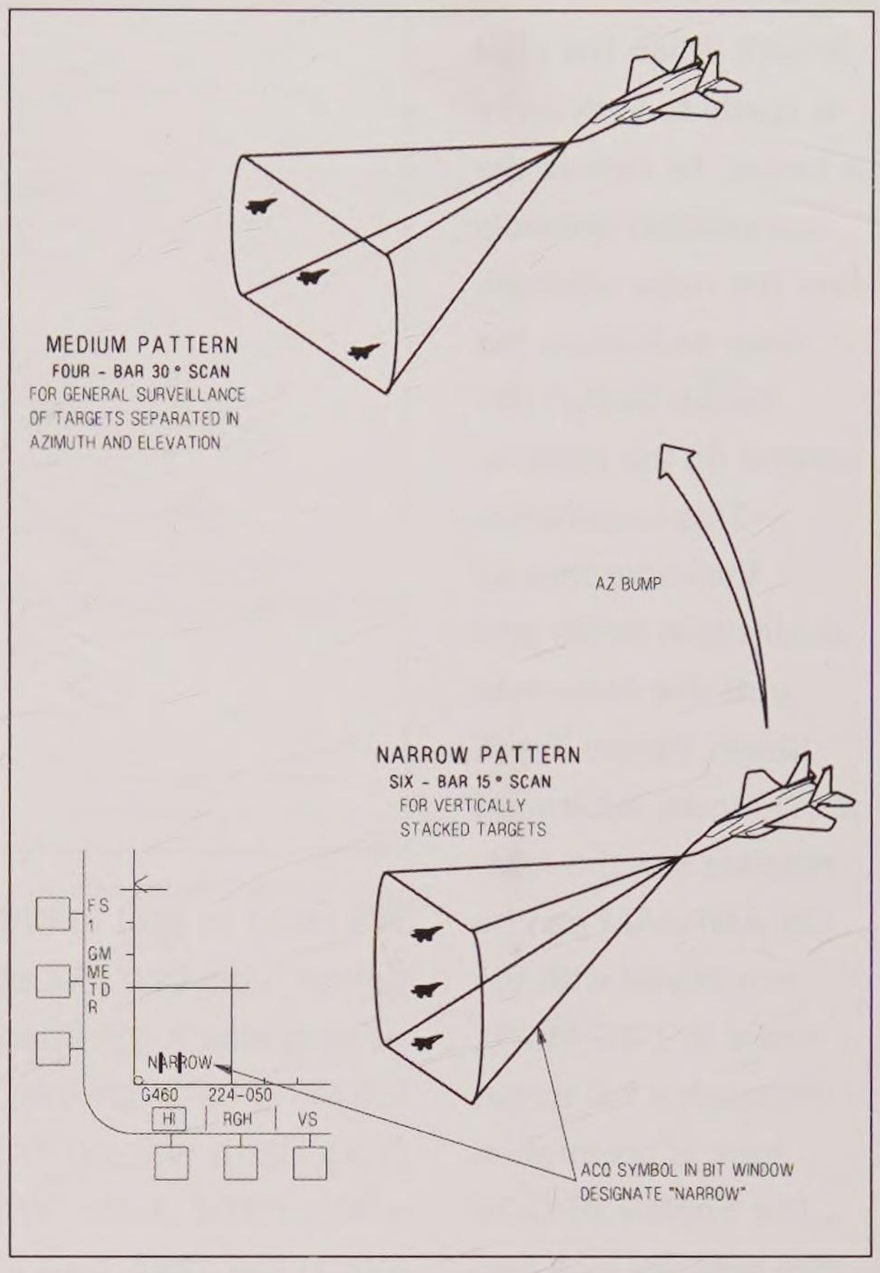
As the bogey blob approaches the triangle-shaped bullseye destination symbol I call 'Timex, Timex.' This means we hack the clocks – we have to command this airspace for the next ten minutes – and that it's time to 'meld' (overlap) our radars: every one of us uses our left pinkie finger to roll the elevation wheel ('L-wheel') on the left throttle to bracket the target's altitude.

'Three's clean low.' As Scout melds, he

**LEFT Super Search auto acquisition mode searches a greater volume of sky ahead but will still lock on to the first target it sees within ten nautical miles.** *(USAF)*




**ABOVE In contrast to the automatic acquisition modes, track-while-scan (TWS) is a multi-purpose mode that can be used to track multiple targets while still scanning for others.** *(USAF)*

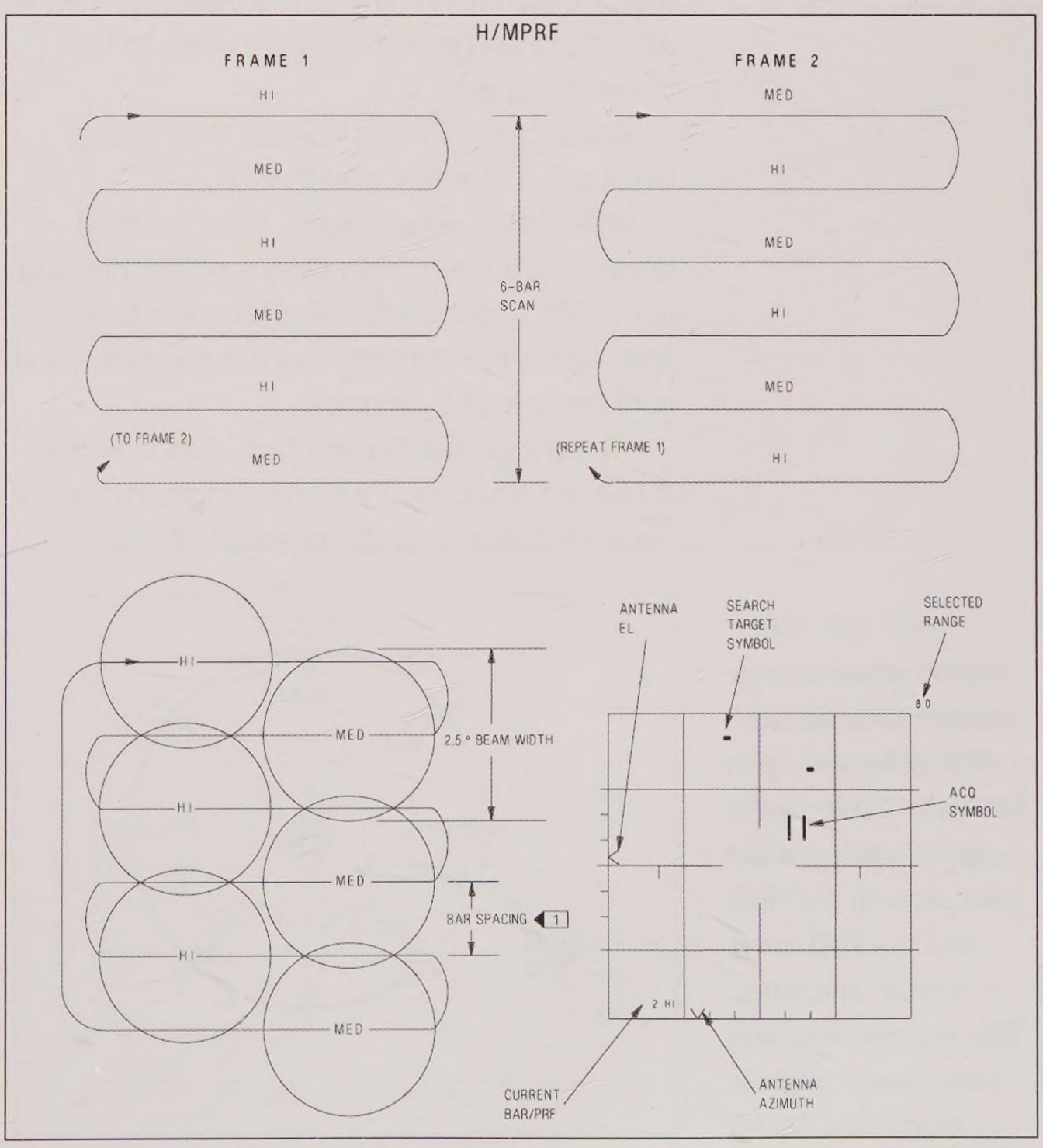



**ABOVE TWS offers different patterns, set by the pilot, to accommodate the likely presence of different formations of target aircraft.** *(USAF)*

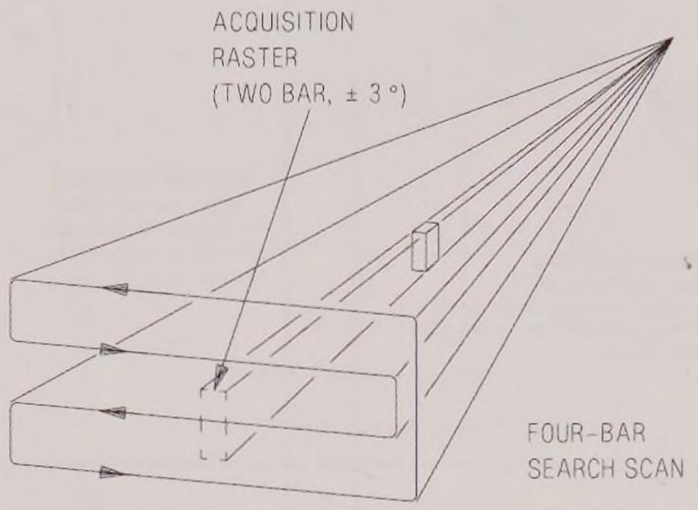
confirms that he's seen nothing in the 'surface and up' band. Good news, only one group, and we've got them surrounded!

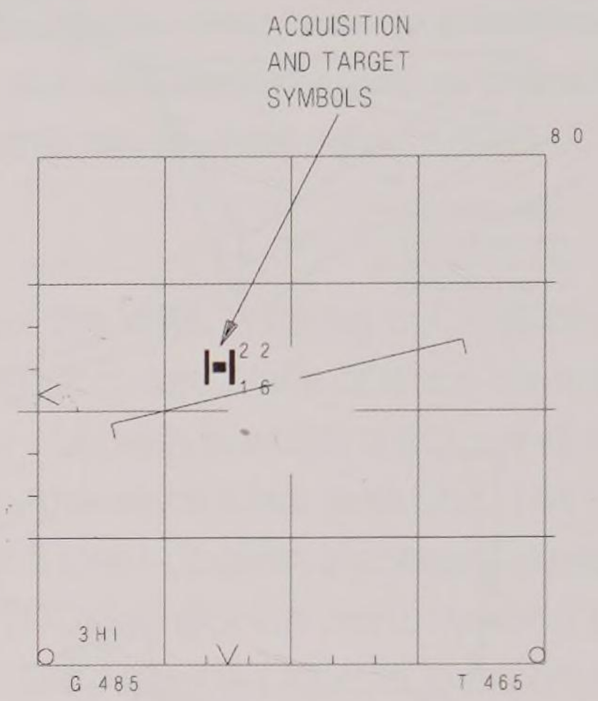
Not so fast – as the glob approaches 'Omaha' it begins to split, becoming two distinct groups … then three. What's it going to be? The 'exploding cantaloupe'? The 'Polish heart attack'? The 'devil's pitchfork' (the Russians' own nickname for a pincer attack)? I see two groups side-by-side, but the third one has quickly faded (disappeared).

Time for us to go to work – moving my TDC atop one group then the other, I call out the information presented on my VSD. 'Lead's got two groups, side-side, both high.' Scout confirms contact with the south group – good. Both of our elements have contact on the bad guys; time for the tactic.




**RIGHT TWS interleaves high pulse repetition frequency (PRF) transmissions with medium PRFs. This ensures the best combination of maximum detection range and accurate target range and velocity data.** *(USAF)*




**RIGHT When the pilot is ready to lock on to a target, he moves the acquisition symbols over the radar contact, then depresses the target designator control on the throttle. This commands the radar into an acquisition raster and puts the radar into Single Target Track (STT) mode. Advanced missiles like the AIM-120 AMRAAM can be employed with the radar in TWS mode, although a full target lock is preferable. The Eagle's APG-70 can actually lock two targets simultaneously in Dual Target Track (DTT) mode.** *(USAF)*

We need to split to engage both arms of their pincer – we can't let either of them get around us and attack the imaginary F-16 package following us. I call the codeword: 'Yogi, Yogi.' (Yogi Berra was an American baseball player who's inane quote 'When you get to the fork in the road, take it', makes it the perfect codeword for a bracket attack.)

Our two pairs of F-15s turn away from each other, Scout and 04 angling south-east to attack the southern arm of the Vipers' pincer, while 02 and I bank to the north-east to take the northern arm.

Scout calls, 'Three's contact third group, Omaha 0-6-0 at ten, one-four-oh.'

Rolling my L-wheel down, I find the third target – he's been 'hiding in the notch' heading north, 90° to our vector, and has now turned west again, towards us – behind and below the northern arm of their pincer.

'Three's gimbal that contact.' Since Scout is headed south-east with his wingman, the northern 'trailer' has disappeared off the left side (his radar has reached its gimbal's azimuth limit) of his VSD – one of us needs to pick him up. Normally a trailer would be the wingman's responsibility, but 02 calls that he's locked to the northern high/lead group. Another debrief item.

There's a tone in my headset that says 'Look at the raw', and I do – two Vipers have locked me up from right one o'clock. Rolling the L-wheel up I confirm that the leader is the one 02 just called 'locked' to, and rolling it back down I re-acquire the trailer. Pressing the interrogate button with my left index finger, I see nothing to indicate these guys are friendly.

'Two, you've got the leaders. Lead's sorted, northern trailer at one-four-oh, hot – both northern groups hostile.'

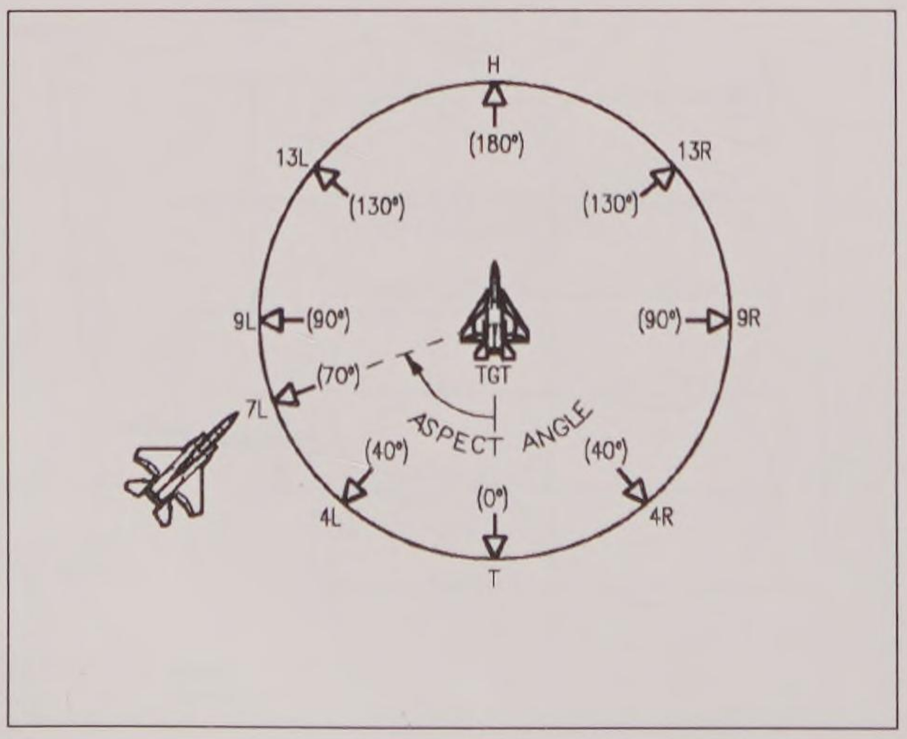
'Two's Fox-three … Fox-three the northern leader, hot at three-four-oh.'

Looking left, I see 02's belly as he cranks away from the approaching threat. He has two AIM-120s (simulated) in the air, arcing towards the lead group and is turning away to stiff-arm the Vipers and stay out of their simulated AA-10 (R-27) 'Alamo' range. I bank to come with him, checking my radar – the trailer is still outside my max range, but he's doing Warp-9 to get there.

'Four's Fox-three … Fox-three the southern bandit at three-four-oh.'

'Two's northern group dragging, missiles trashed!' 02's target – knowing he was the intended victim – turned and ran.

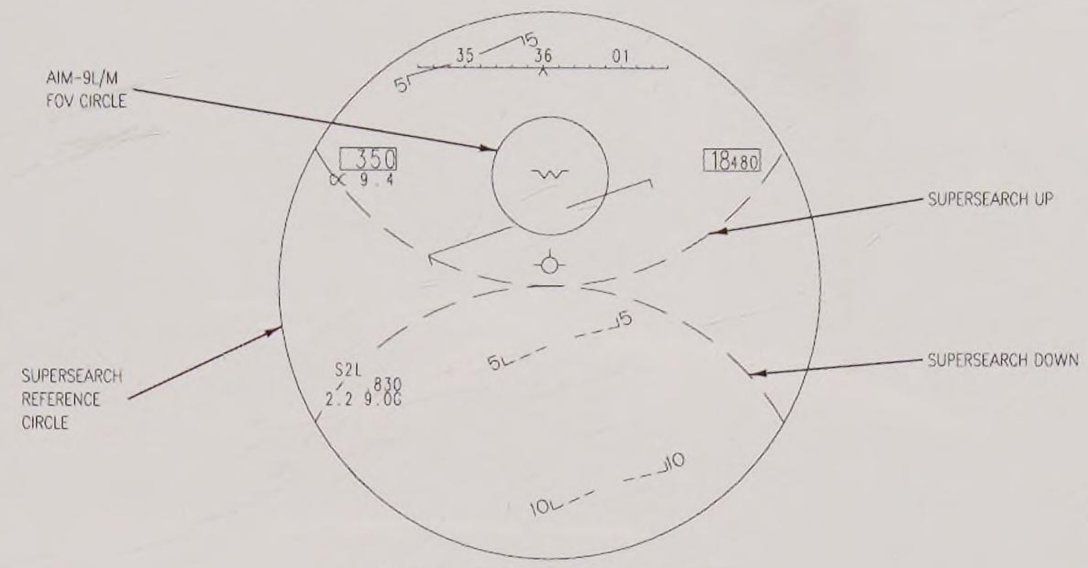
'Monitor,' I order, then I focus on my target – he's just entered missile range, so I roll inverted and pull down, looking through the HUD to place the missile-attack 'steering dot' inside the ASE



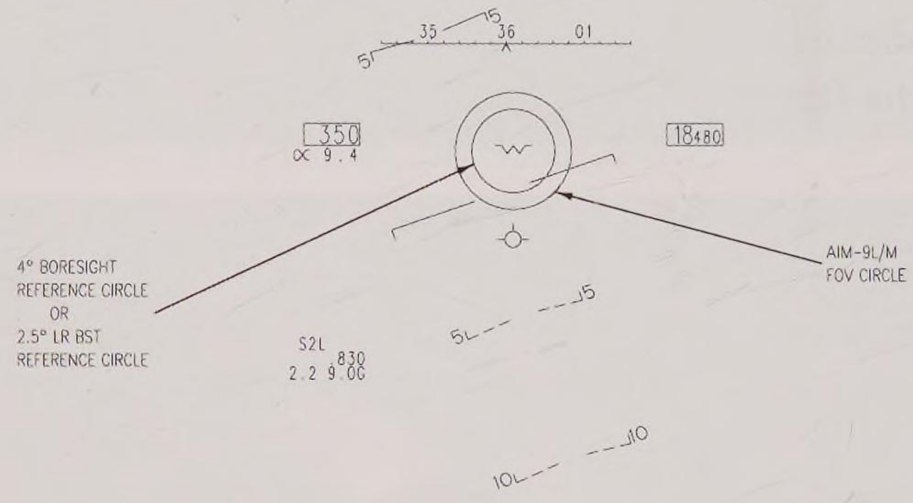

**RIGHT When a radar contact is designated in TWS, or locked up in STT or DTT, its aspect angle is shown to the pilot on both the HUD and the VSD using a number and letter. This diagram explains how aspect angle is calculated** *(USAF)*

**RIGHT The visual indications of two of the SS and boresight modes, as shown on the F-15E's wide field of view HUD. The same indications present themselves in the F-15C HUD.** *(USAF)*

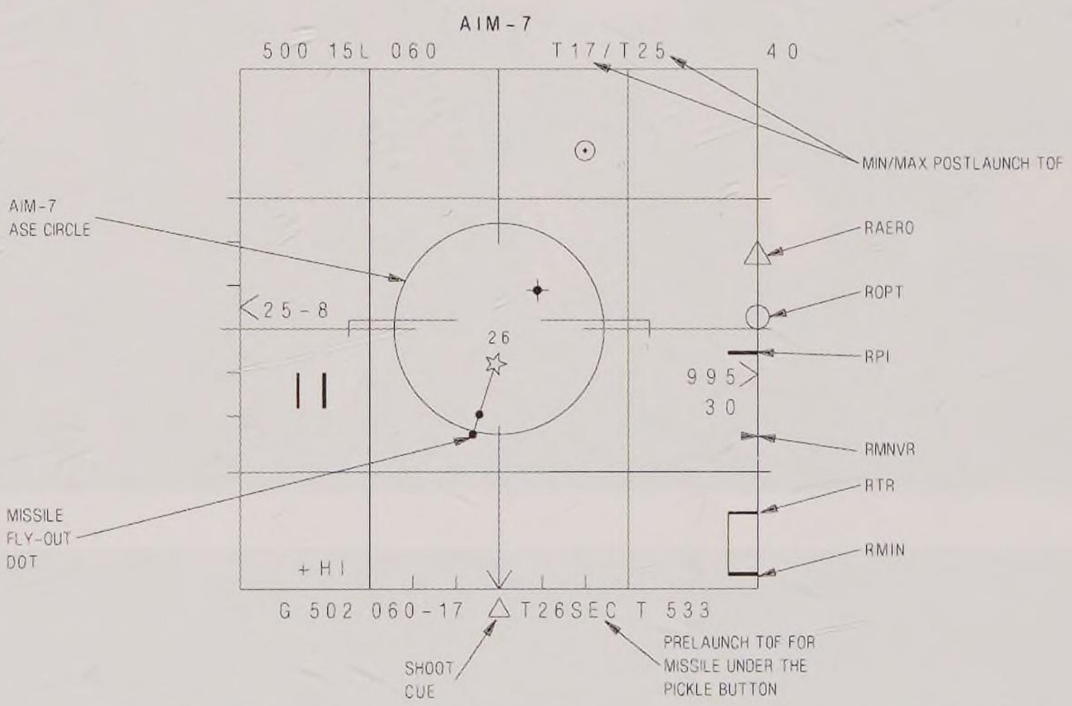
**CENTRE With the AIM-7 Sparrow selected, the VSD displays a range of employment data for the pilot. The ASE (allowable steering error) circle shows where to point the Eagle's nose to ensure that the missile seeker will be able to receive the radar echoes from the APG-63/70, while a bar on the right side shows the maximum, optimum and minimum ranges for the missile.** *(USAF)*

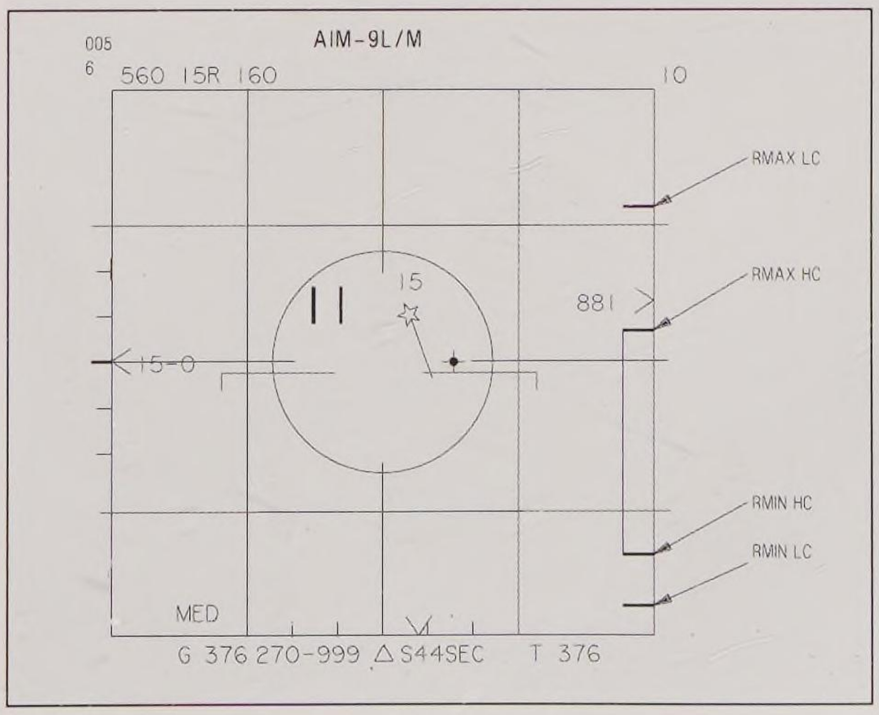



1. SUPERSEARCH SELECTED, SRM




2. BORESIGHT SELECTED, SRM




**LEFT The AIM-9 symbology on the VSD. Like that of the AIM-7 and AIM-120, much of it is repeated on the HUD.** *(USAF)*

(allowable steering error) circle, interrogate one more time then firmly press the pickle button… twice. 'Lead's Fox-three … Fox-three the northern trailer, hot at one-four-oh, crank left!'

As I bank left and pull, descending into the 20s to 'stiff-arm' the trailer, Sentry announces, 'New group, Omaha 3-4-0 at ten, low, headed north!'

The northern leaders have split up – one high running east, the other low heading north!

'Two, say contact, BRA,' I order, telling 02 to change to bearing-range-altitude format; it is much easier to process when time is short.

'Two's bandit is 0-9-0, 12 miles, three-one-oh, still dragging.'

'Drop him, find the low guy…' Sometimes the comm breaks down to just speaking plainly!

'Four's Fox-three kill the southern bandit!' The south side of our fight is going well – splash one Viper – and Scout orders, 'Four, come off left, 0-6-0 – Disco, status?'

'Offensive,' I say, but I'm not sure I mean it – I've got two Slammers timing out on the trailer, who is now trying to turn and run, but the other two Vipers are uncomfortably close, one east and one north.

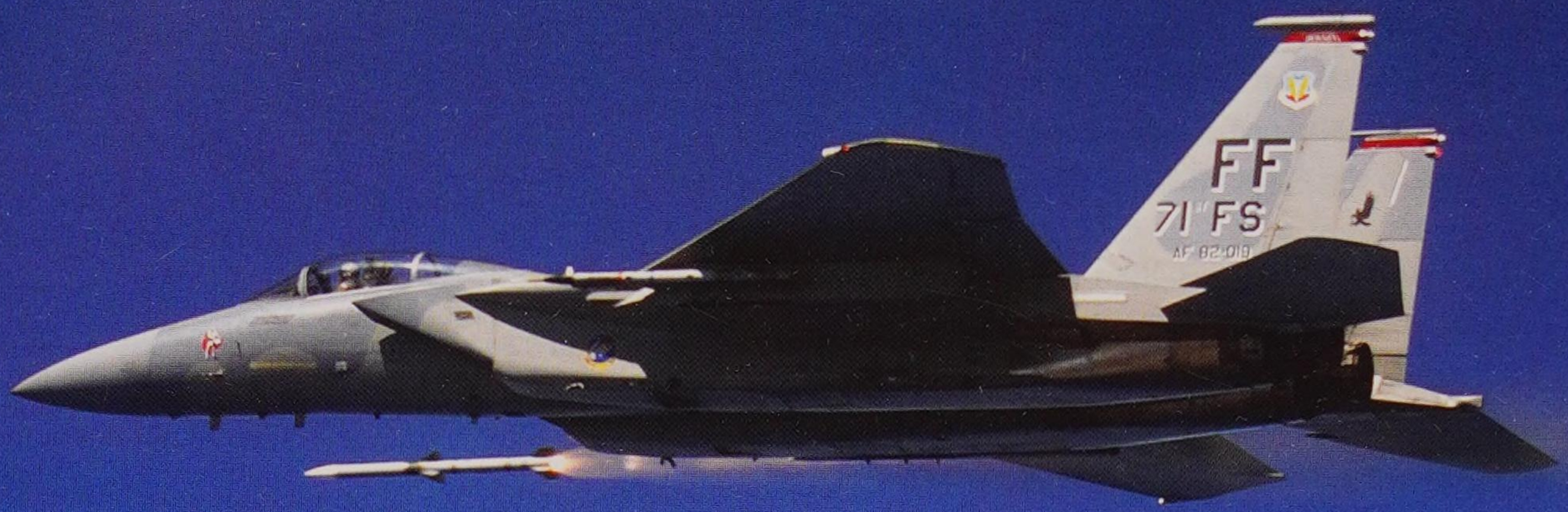
'Four, reference Omaha.' Scout has just directed his wingman to head to the bullseye CAP point, leaving us to handle the three Vipers in the north.

'Two's locked, single target, 40-left at ten, turning hot at one-four-oh.'

I don't have to say it, but I do: 'Shoot him! Shoot him!'

'Bandit, bandit, Fox-three … Fox-three!'

Meanwhile my AIM-120s time-out (simulating



**ABOVE The AIM-120 AMRAAM, informally called the 'Slammer', provided the mature MSIP F-15C with its most awesome capability: the ability to simultaneously target as many individual adversaries as 'Slammers' on board, without tying the radar specifically to any of them. Here the 71st FS 'flagship' unleashes an AMRAAM on an unsuspecting target drone during a Weapons System Evaluation Program (WSEP) shoot.** *(USAF)*

impacting the target) as the trailer completes his turn to run. 'Fox-three kill the northern trailer, one-four-oh, cold.'

Breaking lock, I roll my L-wheel up to the higher altitudes to find the last bandit – sure enough he's at FL300 headed east, 12 miles away, still dragging out of the fight. Another raw tone rings in my ears and I check the RWR to see that a Viper's targeting me from left ten o'clock close.

'Lead's spiked left ten, breaking…' Wracking the Eagle into a right bank, I pull to put the new shooter on the beam (nine o'clock) then roll back left and pull down, my left hand whacking

**CENTRE AND LEFT Visibility from the Eagle cockpit is excellent. A single-piece front canopy and a main canopy that is almost at elbow level allow clear views ahead, above, below and behind. In a business where the expression 'lose sight, lose the fight' is written in blood, this excellent visibility is a major advantage.** *(Ben Cook via Steve Davies and USAF respectively)*

at the chaff/flare dispenser lever on the left side of the throttles as my g-suit hardens, squeezing my legs and gut, and I strain against the mounting gs. Twisting my head up and left I look out the top of the canopy to find the imaginary missile to defeat it, and hopefully see the shooter against the blue-grey sea below.

'Two's Fox-three kill the northern bandit southbound at one-four-oh!'

With the 'MiG' dead his missiles go stupid, so I can quit now. Whew! But the violent manoeuvring's broken my radar lock and, twisting around, I don't see 02 – I'm 'tumbleweed'.

'Sentry, picture!' I order.

Sentry reports 'Single live bandit, Omaha 0-5-0 at 12, headed east at three-zero-zero.'

'Scout's Omaha, in the 20s, cold.' Eagle 03 announces that he's established the CAP to cover our imaginary strike package's ingress.

'Two, you visual?' I ask, slowly filling my 'clue bag' again as I put my radar on the fleeing Viper.

'Two's visual your left nine [o'clock] high.'

Squinting as I look up into the bright blue sky I see him, small and light grey, slightly ahead and high – I rock my wings to get him to collapse into a better tactical formation and lock up the last live Viper. Checking my nav info, I see we're past north of Omaha. Time to go to the CAP – as 02 collapses into a proper tactical formation, I give him a hard wing-dip to the right, directing a 90° tactical turn to south. In his turn, he crosses high behind me. I bank and turn easily at first – I want to keep the Viper illuminated with my radar (*ie* have my 'spike' show up on his RWR) for as long as I can to keep him running out to the east, thinking we're still after him ('pushing' him).

'Scout's hot, contact Omaha 0-9-0 for 20, hot at two-four-oh. Bandit, bandit, commit!'

'Four's clean low.'

As 02 and I approach the CAP point, we see Scout and 04 pass across our noses high, headed east to engage the first 'regenerated' bandit. Arriving at Omaha, 02 and I turn right ('cold'), wait a couple of potatoes then in-place (180°) turn to east and start building a radar picture of the developing fight. Scout's single bandit drags out (rather than get killed again) and he calls returning to CAP, while 02 and I cover them, picking up one bandit coming in from the north-east (the last live Viper) and kill him while the other two targets regenerate and approach from the east, low. The result is a confused slugfest that will have to be sorted out in the debrief. We get two more kills – Scout Fox-three's one, and 02 gets another with a heater (AIM-9) while I'm again pushing another bandit out of the fight with my radar.

No 'kills' are called on us.

The Vipers 'bingo' out one by one, and ten minutes after 'Timex' I call 'Rolex, Rolex', meaning that our 'vulnerability time' has expired, all the imaginary F-16 strikers are through the CAP point inbound to their target and our work here is done. We depart Omaha westbound as elements, with 02 and I picking up Scout and 04 at the western edge of the airspace.

'Fence out.'

## Refuelling

Levelling off at 24,000ft we check out with airspace control, get a vector to the tanker track and, once we've got radar contact on 'Exxon 11', we're sent to the AAR frequency. Exxon 11's in his turn at the end of the track, so the intercept and join-up will be expeditious – I 'rock my wings' to have everyone close to fingertip formation and pass the 'check' sign (thumb and forefinger extended) to Scout, telling 04 to do a quick 'battle damage' check. Eagle 04 climbs slightly to visually inspect the topside of Scout's jet for any wrinkled skin and missing panels, then dips down beneath him to look for the same plus any fluid leaks. He

**BELOW A 110th FS, 131st FW F-15C tanks mid-session, during an exercise with the Terra Haute, Indiana, ANG's F-16s. The Eagle's long-look radar led to the F-16 community developing the 'exploding cantaloupe' tactic to give them a chance that at least one aircraft might make it to the merge!** *(Steve Davies/ FJPhotography.com)*

**ABOVE A gaggle of 123rd FS, 142nd FW MSIP-As from Oregon's ANG hits the tanker.** *(USAF)*

scoots across underneath each of us, inspecting our jets, and then climbs above 02 to check his topside. He returns to his own position without comment – meaning everything's okay – and I waggle the tails to send everyone out to a looser en-route formation.

With the KC-10 approaching my ten o'clock position, 180° out and slightly high, I begin banking towards him to fly the intercept curve and call for a fuel check to see if anyone needs priority on the boom. Sounds like the normal flight line-up will work. This is also the signal to accomplish our pre-air refuelling checklist – which most of us memorise as the 'BRITES'

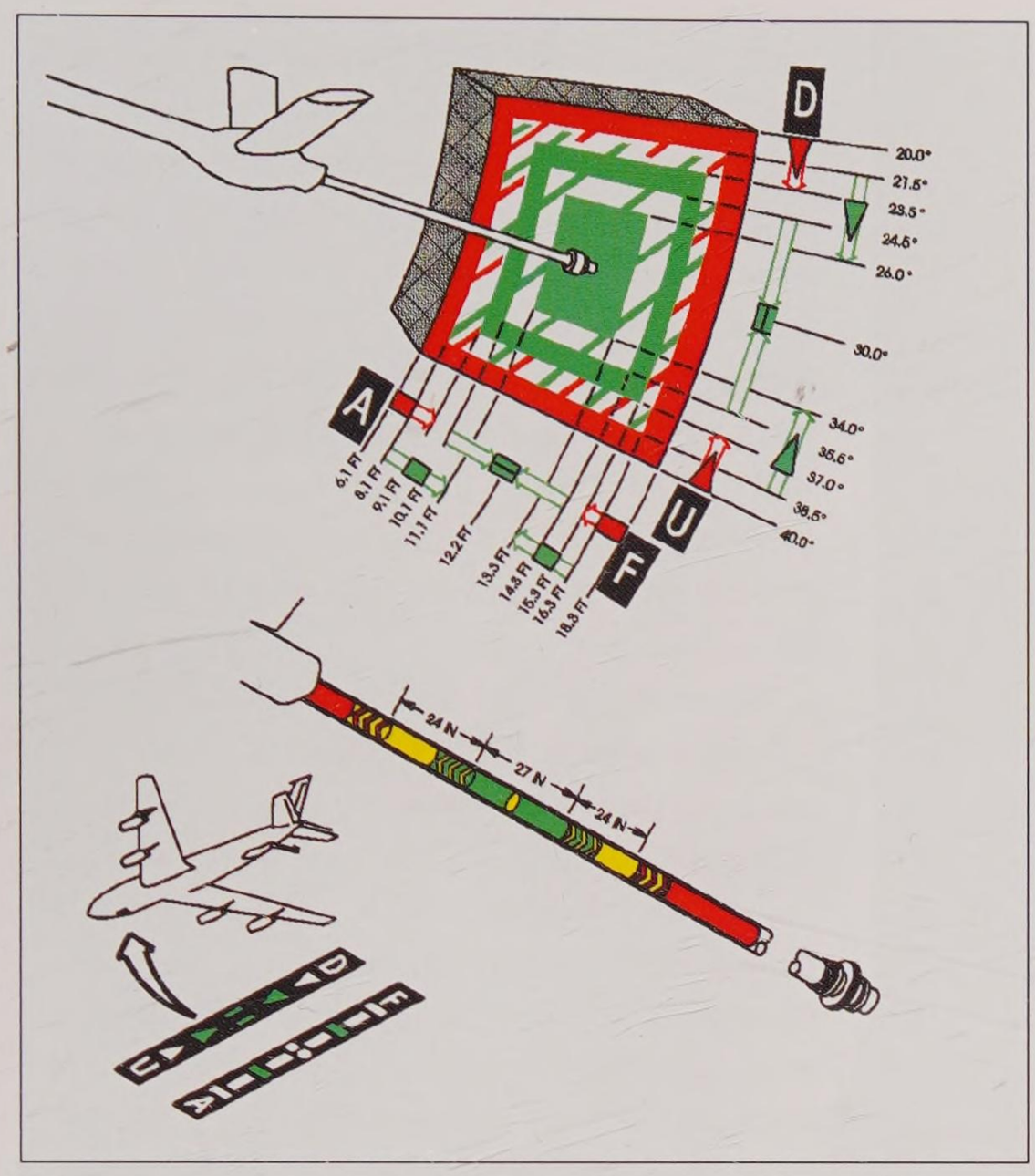
**RIGHT A 32nd FS F-15A replenishes its fuel from a KC-135 high over the Iraqi desert. Tankers were considered high value assets because they enabled the Eagles to stay on station and often provided the fuel needed just to get back to base, especially with the more fuel-limited MSIP-A models in Operation Provide Comfort. Notice the pilot's stylish desert tan flight suit.** *(USAF)*

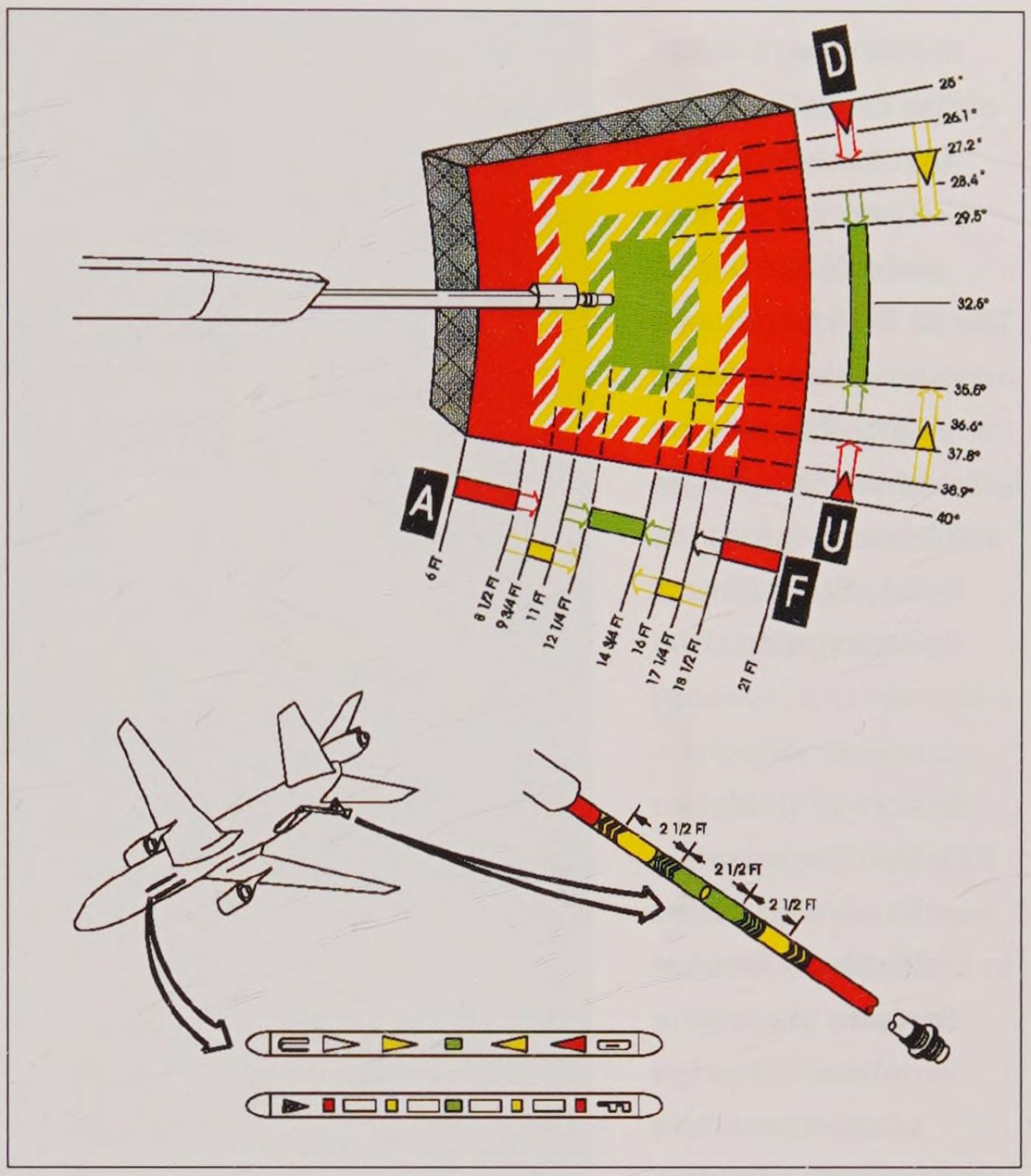
**ABOVE The F-15C distributed mission trainers allow the Eagle pilots to fly high-fidelity combat missions on the ground. Here the view approaching the tanker is seen. These Boeing-developed tools can be linked electronically to allow pilots at one Eagle base to fly combat against other pilots in other Eagle squadrons anywhere in the world.** *(Boeing)*

check: beacon, radar, IFF, air-to-air TACAN, and any other emitters – 'OFF', slipway door – 'OPEN'. The AAR 'READY' light on my canopy bow illuminates, indicating the AAR receptacle is open for business.

Swinging around into the KC-10's six o'clock, we're sent to the 'boomer's freq' (boom operator's frequency) and check-in. I send my wingmen to the tanker's wings – 02 on the left, Scout and 04 on the right – as I motor forward into the pre-contact position. The boomer lowers the winged tube, signalling me forward. Add a bit of power and the Eagle pushes ahead, and I guide it past the end of the boom and stabilise beneath the tail of the big jet; the boomer does the rest. The AAR receptacle is atop the left wing root, so I offset to the right, my nose pointed beneath the KC-10's right-hand main landing gear door, and push my left-hand mirror outboard a little to see the boomer guide the tube to the receptacle and plug it in. The AAR ready light on the canopy bow extinguishes, confirming contact, and almost immediately the gas flows.

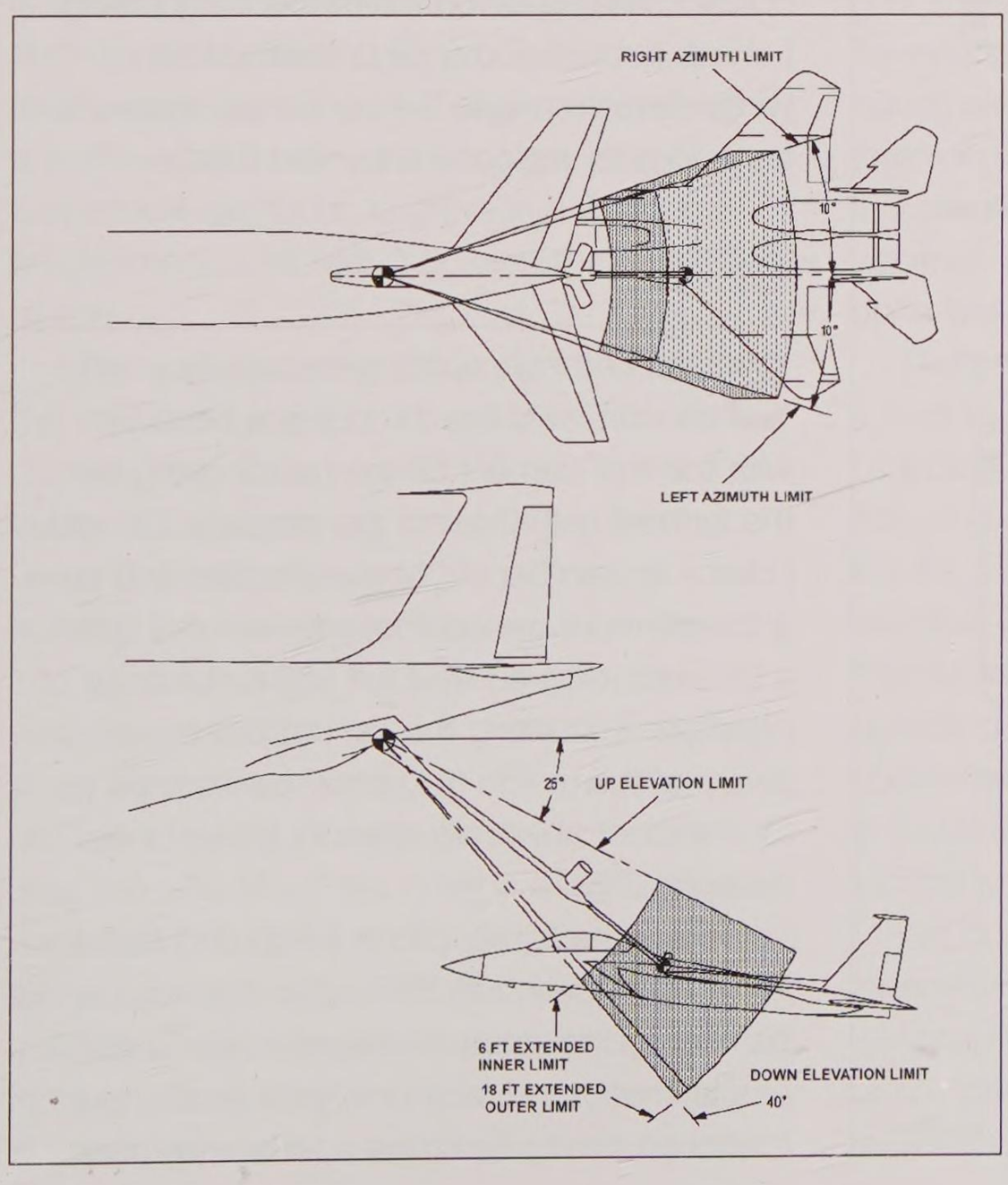
I check the director lights on the tanker's

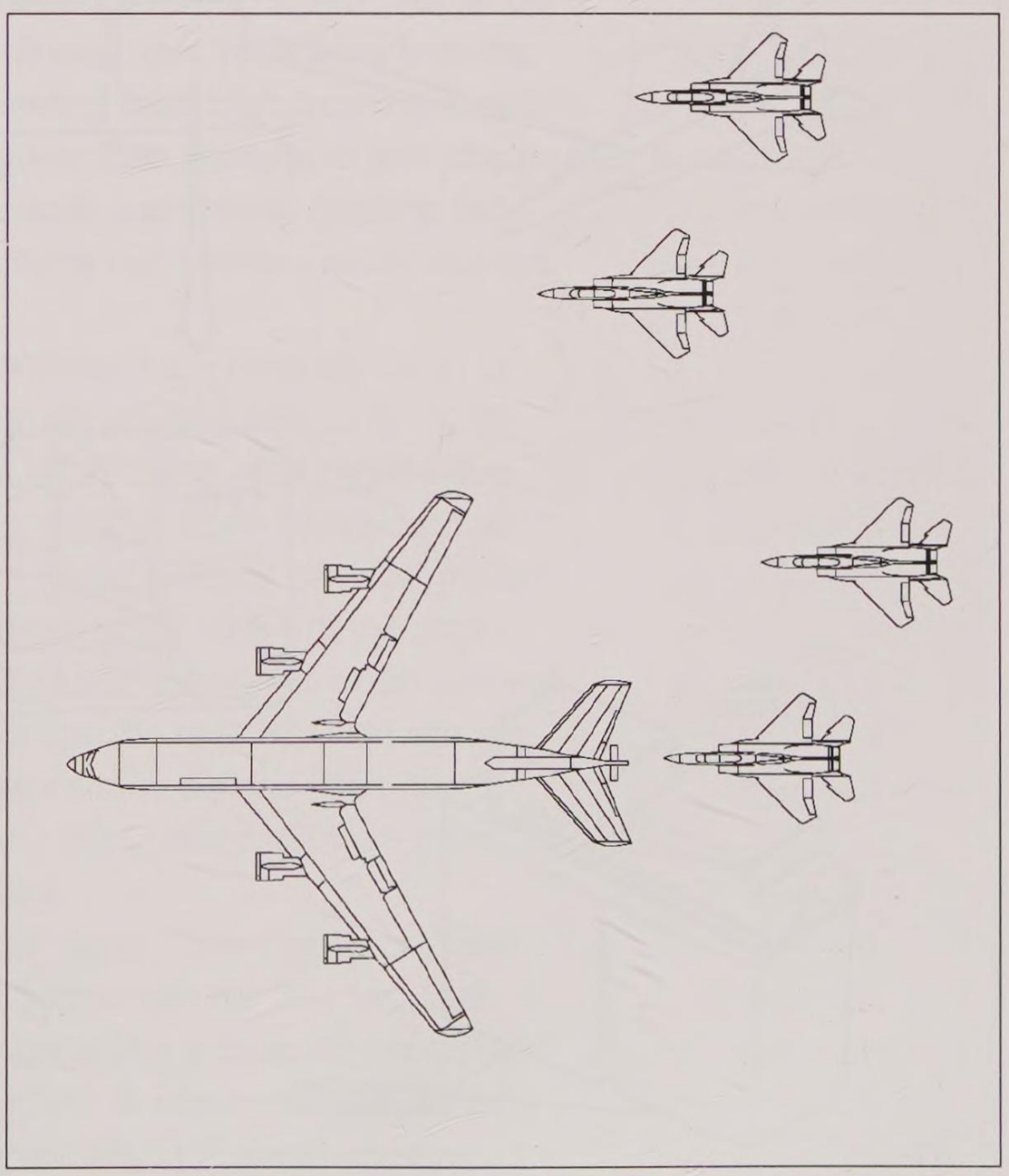



**ABOVE AND BELOW** The KC-135 (above) and KC-10 (above right) have boom limits and indicator lights that the Eagle pilot must observe and be aware of. In daylight a visual sight picture will develop in the pilot's mind that will make observing these limits simpler. But in the dark of night the indicator lights may be the only reference available for position keying. *(USAF)*

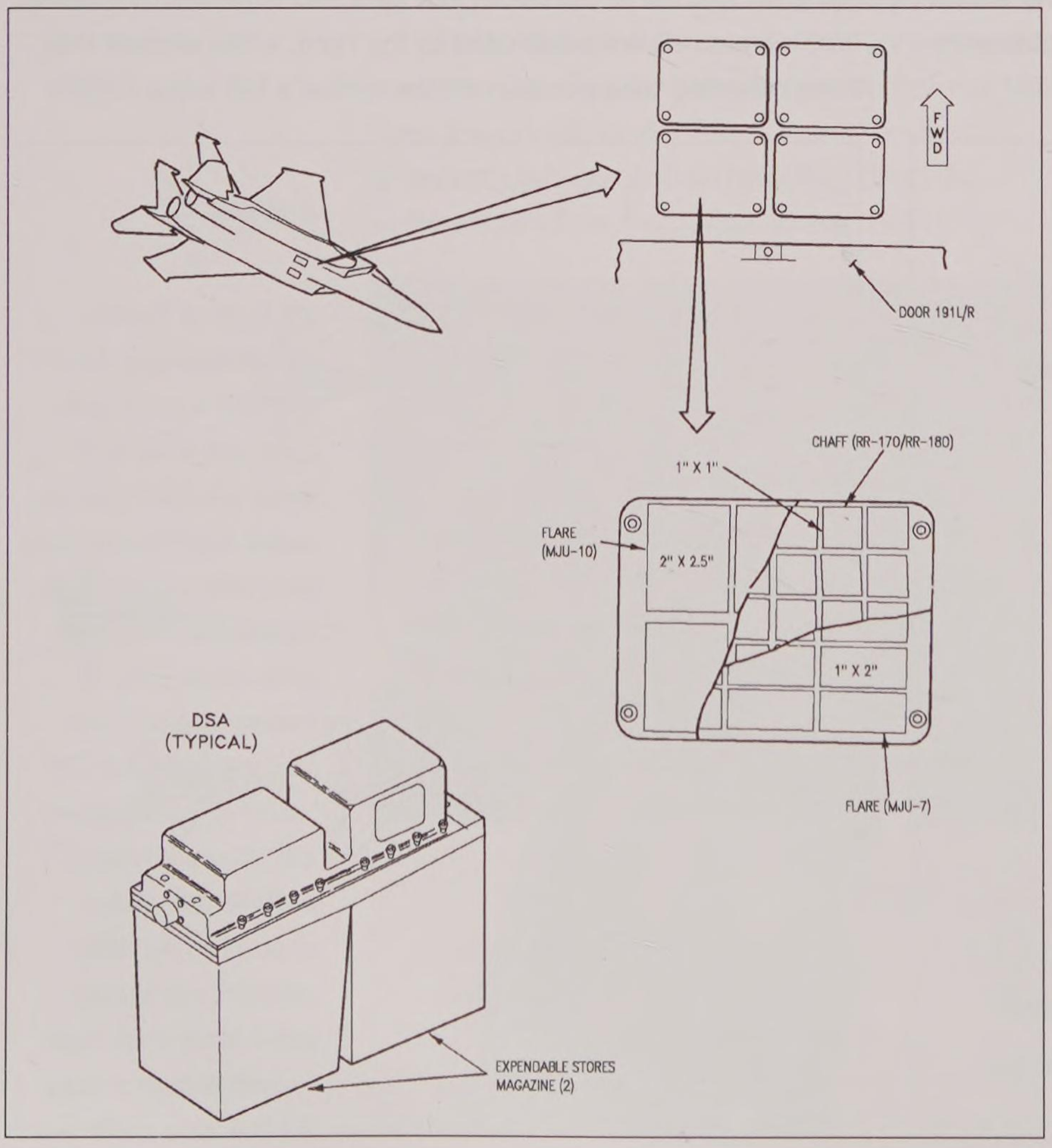
**BELOW** The 'quickflow' pattern allows a flight of Eagles to cycle on and off of the boom in a safe and expeditious manner. Waiting aircraft are positioned to the right, while aircraft that have refuelled take position off the tanker's left wing. *(USAF)*



**RIGHT Two F-15Cs of the 110th FS, 131st FW, Missouri ANG, pull into the vertical and release flares. The ALE-45 CMDs can accommodate MJU-10 and MJU-7 flares, the latter of which is larger and burns brighter (as here).** *(Steve Davies/ FJPhotography.com)*

**BELOW The counter-munitions dispensers in the F-15 are located beneath the engine intakes. A range of chaff and flare types can be loaded, according to the expected threat for the mission.** *(USAF)*




belly, make some fine adjustments to ensure I'm in the best position and relax. While the immense size of the tanker and the knowledge it contains tons of highly volatile jet fuel can be psychologically intimidating, the actual task of refuelling is as easy as any other kind of close formation flying. We're getting a top-off to refill the internal tanks for BFM, and as soon as that happens I push the AAR release button (normally the stick grip's auto-acq button, except when the slipway switch is 'OPEN') to eject the boom.

Reducing power I slide back, and, once clear, bank left to cross beneath 02, then climb up on to his wing. He makes sure I'm there before dropping down and sliding over to the pre-contact position. I monitor 02 until he's plugged in and looks stable, then I go to the controlling agency's frequency in the aux (radio) and coordinate our departure from the tanker track and clearance back into the airspace for BFM. By this time, Exxon's reached the other end of the track and begins a turn. I check 02 to be sure he's handling the bank, and monitor him until he's got his gas and drops off the boom, scooting out left, passing behind and beneath me to show up on my left wingtip.

As Scout moves down and over to pre-contact, leaving 04 on the tanker's right wing, I check out with Exxon and climb off his wing, switching us to the controlling agency's frequency for airspace entry and BFM.

## BFM

Scout and I are splitting the airspace with an east-west line through the bullseye, with the first element off the tanker going to the farthest half. Once in the airspace, 02 and I check in with Sentry, fence-in again, and do a couple more g-awareness turns – this time a 90° turn followed by a full 180 (to practise physically sustaining the gs, not just being aware of them) – to get ourselves warmed up for the most physically strenuous part of the mission: BFM.

BFM is the fighter pilot's bread and butter – ironically it doesn't much matter that you can kill bandits by the score on the video game (BVR employment); if you can't fly your jet and put it where it has to be to get a kill or stay alive,

**LEFT The small antenna ahead of the windshield belongs to the improved ALQ-135B jammer, which gives the Eagle superior protection against a broader spectrum of threat emitters. Combined with the digital ALR-56C radar warning receiver, it conferred a superior operating capability in multiple, high-density threat environments. A second, identical antenna is located behind the radome, underneath the fuselage.** *(Steve Davies/ FJPhotography.com)*

you've no respect in a fighter squadron. BFM is the art and science of manoeuvring your jet against an aware and aggressive bandit who is actively manoeuvring his own to defeat your shot opportunities and kill you instead. It is the dynamic blending of energy management and lift-vector control, plus another dozen less critical elements, to arrive in a weapons employment zone (WEZ) or keep the bandit out of one.

While judicious energy management creates the continued ability to turn your jet, lift vector control determines where it will go. The lift vector is that imaginary arrow that extends upwards perpendicular to the jet's wings, pointing to where the jet's nose will go if you add g – the more g, the faster it goes there, airspeed permitting – and is mentally visualised as an extension of your own spine. Pulling hard and looking directly above the canopy bow you see where the nose is going – you want that to be the bandit's six o'clock when manoeuvring into the WEZ (the AIM-9 and gun employment envelope aft of the bandit's three to nine o'clock line) and, once there, out in front of him when you're trying to bring the nose, the gun and the heater to bear. If starting defensive, you roll to point the lift vector into the bandit's deep six and pull max allowable g or angle of attack (AOA) to rotate your jet on its wingtip, swinging your WEZ away from the bandit and creating such high crossing angles that you deny him valid heater and gun attacks. It is simultaneously a physically gruelling but viscerally gratifying experience – much like sex done well.

The g-awareness turns have set us up in a lead-trail formation with Eagle 02 at my six o'clock about a mile back. He'll be offensive first – I give us a 30° in-place 'check turn' to the left, so I'm now looking at him over my left shoulder (seven o'clock) – he's at the edge of the old AIM-9/Atoll IR missile envelope and well outside gun range. We're at 18,000ft altitude above the water's dark surface (area floor is 10,000ft) and doing about 430kt, a good tactical airspeed.

We both call ready, I say 'Fight's on,' and manoeuvring begins with his 'Fox two' call.

I snap the Eagle into a deep left bank (120° or so), pointing the lift vector beneath his jet's tail (deep six), my left hand karate-chopping the

**RIGHT Weapons loads depend upon a number of factors, but the early preference for four AIM-120s and four AIM-9s (pictured) had been superseded by the time the 'Grim Reapers' participated in OAF. Instead, the more common loadout was two AIM-9Ms, four AIM-120s (two on the wing pylons) and two AIM-7Ms.** *(USAF)*

chaff/flare lever on the left side of the throttle as I twist, tense and strain anticipating the high-g onset. I pull back hard and fast, until the OWS (overload warning system) chirps its high-rate beeper in my ears, telling me I'm pulling about as much as I can without over g-ing the jet – approximately 8.5g+.

I see 02 roll and pull his nose to my six o'clock, flying his jet towards the WEZ that's trailing me, disappearing behind my tails with his nose 'in lag' (I'm looking mostly at the top, not the front, of his jet as he disappears behind me). In spite of the spiralling descent I've started, the high gs have begun scrubbing

**BELOW The joint helmet-mounted cueing system is in effect a mini HUD that is projected on to the inside of the pilot's visor. As seen here, it adds a little bulk to the helmet ensemble, but it significantly increases the Eagle's potency and so is worth the trade-off.** *(Steve Davies/ FJPhotography.com)*

**BELOW This is the 'SIT' display for the Fighter Data Link. The data link display shows an eight-ship wall of Eagles about to engage three pairs of MiG-29s over an enemy airfield.**
*(USAF via Steve Davies)*

**LEFT F-15C 85-119 – the same jet in which Captain Rhory 'Hoser' Draeger scored his MiG-29 kill on 17 January 1991 – intercepts a 'Bear' over Alaska. This jet was the first F-15C to receive the APG-63(V)2 AESA radar, and was assigned to the 12th FS, 3rd FW, Elmendorf AFB, Alaska.** *(USAF)*

off airspeed, and I relax slightly to what I can physically sustain – about 7g – knowing that this is also the Eagle's best energy-maintaining turn – more g tightens the circle but depletes airspeed (energy); less g widens the turn. Also, knowing that it will be about 60–90° of turn before 02 shows up inside my turn again, I do a quick energy check (airspeed/altitude) in the HUD, clear the flight path ahead and inside the turn, and take a couple of deep breaths to reset my straining manoeuvre, then toss my head over my left shoulder again and bear down hard against my g-suit.

Sure enough, he's coming back to the inside of my turning circle, still about a mile out, his own nose rotating to point at me. I add some g – to slow-rate beeper – and rotate my jet more/faster in front of him, kicking him out of the WEZ and into the middle of my turning circle. His nose continues to pull inside – I'm starting to see some of his belly, the telltale sign that he's pulling 'lead' for a gun attack. I ease off the g now – to about 6 – and pull the throttles to idle, letting him close more rapidly. Wait for it … Bait him … Bait him …

As he approaches 3,000ft (maximum effective gun), I add g sharply, and with no AB to sustain the speed or g, I quickly feel the subtle tickle in the stick grip that signals my jet's at its best 'instantaneous corner' velocity, rotating rapidly in front of him. To spoil his gunshot, I roll out briskly, point my wingtip at him to make my big Eagle as 'skinny' as possible (knife edge) and pull up sharply, out of his gunsight. Rolling towards him again, I slam the throttles to the stops and point my lift vector to his high six, pulling hard, deep into the airframe buffeting as the wings are shedding knots in droves! (This was a 'jink'.)

02 tries to correct his aim, but rolling out to do so means he's not turning and, by the time he can get back into his bank and g, the fleeting gunshot's vanished and he's sailing past my tail with way too many knots! His speed brake

**BELOW The broken wreckage of a MiG-29 of the Federal Republic of Yugoslavia Air Force following its downing by an F-15C in March 1999. The Eagle is statistically the most successful jet fighter of all time, with 105-plus kills for zero confirmed losses.** *(USAF)*

yawns open in a futile attempt to slow down. I roll right to catch him 'coming out the other side', point my lift vector at his 'burner cans, make sure my throttles are jammed into the north-west corner of the cockpit – the ABs kick in hard (because airspeed is so low their light-offs are much more discernible) – and pull at the tickle to swing my nose towards his six o'clock as he goes scooting forward of my 3–9 line.

Recognising that his offensive potential has just vapourised, he can either turn into me (and go fully defensive) or pull up and away from me. This he does, all of his excess energy now making him zoom up into the blue. I pull my jet around under his six o'clock and roll wings level to 'camp out' below and behind him. However, he's a couple of thousand feet above me, and nothing but an 'I-wish-you-were-dead' missile can get him. I'm now in an offensive position but without a shot.

This is about the same as having a possum or raccoon 'treed' – you can't shoot him, but he can't get down. By the same token, if I turn to leave he'll descend back into my six and I'm defensive all over again. Tactically this is not good for either of us – we're both just 'strafe rags', targets for anybody else to shoot. I 'knock it off'. One of the BFM training objectives has been met: his attack was neutralised.

We roll off towards the wider part of the airspace and settle our breathing and heart rates a bit while we check fuel – 'Lead's 7.4, squared and balanced,' meaning I've got 7,400lb of fuel, both total and internal, and the wing tanks have equal amounts. After midairs and GLOC, the next greatest cause of lost Eagles is their propensity to go into a spin under high AOA if one wing is appreciably (200lb of fuel or more) heavier than the other. So we always make sure we're still balanced before resuming BFM.

This time, I'm offensive. We set up again with a 'check turn' that puts me 30° off 02's tail, to his right side, about a mile back.

'Lead's ready.' 'Two's ready.' 'Fight's on, Fox two!'

Immediately 02 rolls and pulls towards me, bright streamers of flares spitting from his belly and arcing through the air. These indicate where he started his turn and that's where I'm going first. I plug in the ABs, roll left, pull the nose to the streamers, reverse the bank and settle into a hard 7.5g turn behind him. Defensively, angles determine the results; offensively, energy dictates, so I bide my time, holding the g and sustaining my corner velocity, working my way around his turning circle, noting that he is spiralling downwards trading altitude to sustain speed and g. With equally matched jets, this will continue to the floor of the area and then settle into a flat, continually decelerating and equally unsatisfactory 'circle jerk'.

I pull my nose into his turning circle once; he counters effectively by increasing the angles again, and I decide this has gone on long enough. Relaxing g slightly to slide back on to his turning circle, with my nose lagging about 30° behind him, I roll out slightly, reducing my spiralling descent, building some vertical turning room between us as he continues downwards. This costs me airspeed, but I'm now climbing (relative to 02), because as the turning continues geometry swings my nose inside his turn again. Once my nose has swung ahead of him, I roll, put my lift vector well out ahead of him and pull hard – stick 'tickling' my fingertips – bringing my own nose to an imaginary intercept point ahead of him.

Recognising that I'm swooping in for a gun attack, he rolls out slightly to arrest his descent (minimising my vertical turning room) then sets his bank to rotate his jet in front of me. I pull a little more lead, centre the gunsight 'in plane' ahead of his nose and squeeze the trigger as he enters the reticule. He recognises it and jinks 'out of plane', passing just above the pipper.

I call 'Snapshot!', roll left, and pull hard to his deep six, count five potatoes, unload and roll out – pushing the stick forward to get light in the seat (about 0.5g, minimising induced drag for the best acceleration) and making sure the throttles are jammed in full AB. Checking over my right shoulder I see 02 has reversed his turn, rotating his jet hard to get a 'fade-away jump shot' (as in basketball) as I'm exiting the fight, accelerating through the Mach, angling downhill, getting close to the simulated ground (airspace floor) where the thicker air shrinks my WEZ. I give one quick turn to the right to rotate my WEZ away from him and watch as his jet diminishes to a dot.

'Good separation,' 02 calls, meaning I've

gotten away – he's got no shot. I call 'Knock it off' again. We rejoin to tactical, I point us into the wider part of the airspace and we climb back up to 18,000, checking fuel and taking a moment to get our breath and strength back.

The final set-up is for a neutral engagement. It begins with us in tactical formation, line abreast level, and I call 'Turn away.' We each make a 45° turn away from the other, and after the distance between us increases to about four miles (read on the air-to-air TACAN) I call 'Turn in.' We roll and pull towards one another, both level, approaching each other at 480kt (over 1,000mph combined!), offset slightly to one side.

As we turn in, I practise my weapons employment – 'Never pass through a WEZ without shooting something' – using the vertical scan auto-acq mode (the radar scans up and down the lift vector and locks on to the first target in this slice of the sky). I lock him up and thumb forward to MRM (medium-range missile). Never taking my eyes off him as we pull our noses towards each other, as soon as the 'lock-shoot' lights on the canopy bow start flashing I know I'm in the AIM-120 WEZ and mash the pickle button, hesitate for the Slammer to clear the rail, then thumb to SRM. As soon as I hear the heater's buzz in my headset I uncage, get the self-track tone, check that it's eagerly circling 02's jet, and push the pickle button again. These shots don't count, but if 02's not getting the same practice it'll be a debrief item.

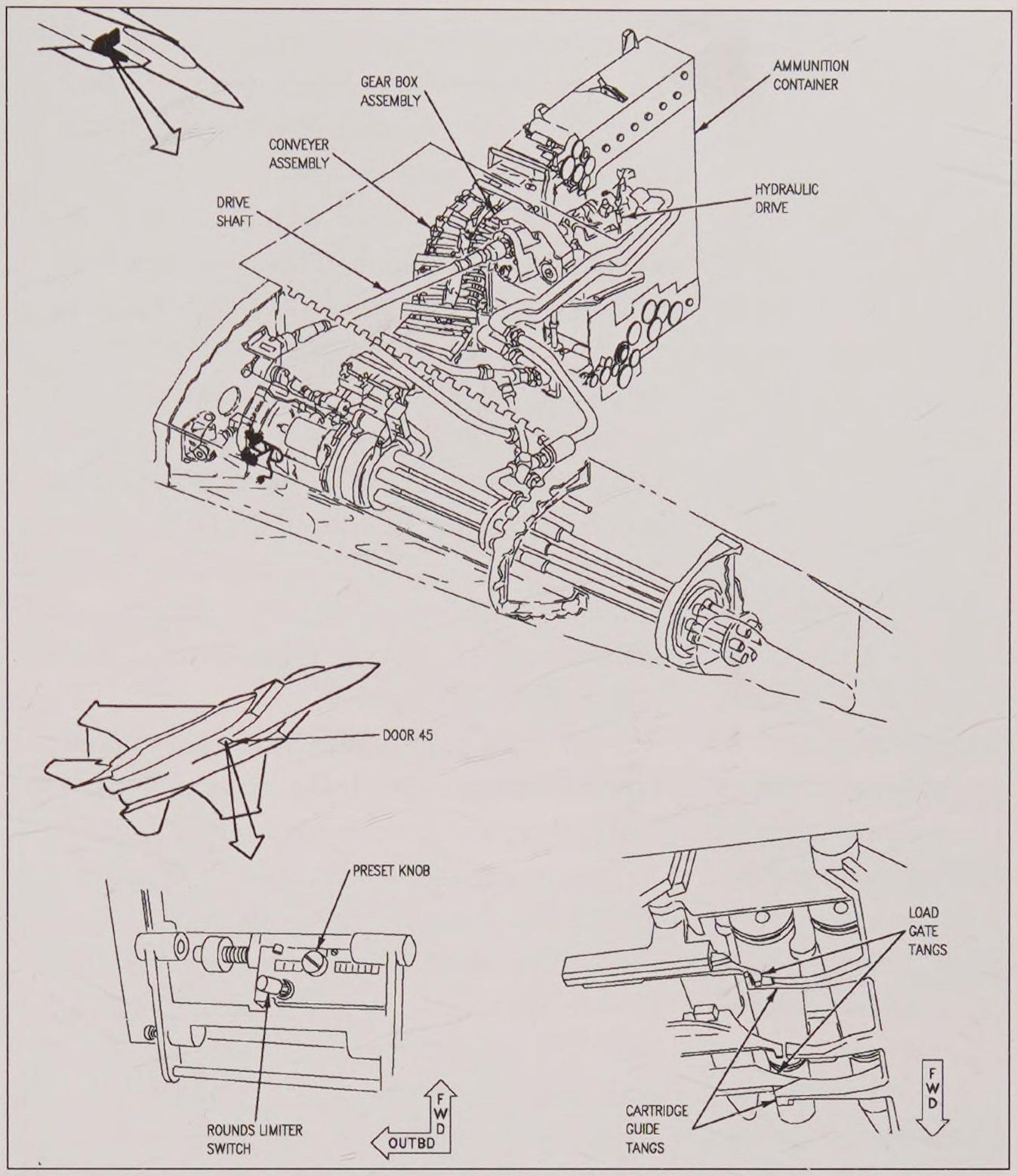
Just before we merge, I call 'Fight's on!'

Like knights jousting, it's a left-to-left pass, but as soon as the words are out of my mouth I pulse the stick to get an upward vector, and the instant I've cleared 02's jet (by the required TR distance) I wrack it into a 70–80° bank towards him, pulling across his canopy in full blower at high-rate beeper.

Neutral BFM can be flown in either a 'two-circle fight', in which both fighters turn towards each other at the merge (lift vectors aimed at each other's six o'clock) and continue turning for 360° until pointed at one another again (looking like a 'figure eight' if seen from above); or a 'single-circle fight', in which one fighter turns belly up to the other at the merge (both pointing their lift vectors into the centre of the same circle) and meet each other after only 180° of turn (from above the two jets describe only one circle).

A 'two-circle fight' is also a 'turn-rate' fight, in which – all other things remaining equal – the fighter that generates the greater rate of turn will eventually arrive at one of the subsequent merges with a significant angular advantage and can convert that to a position of advantage behind the other jet. A 'single circle fight' by contrast is, from the outset, an 'angle' fight in which sustained turn-rate performance is not as significant as judicious use of quickest, tightest turns to bring the nose to bear.

To me, one of the keys to winning neutral BFM is to not be on the horizon when your adversary rotates his jet around and can see out the top of his canopy, searching for you. Consequently, once I'm in 02's blind zone I roll out slightly to start climbing, once again creating vertical turning room. Airspeed diminishes and my turning circle widens, but looking back and down I find 02 quickly – light grey stands out starkly against the dark blue water – while it




**ABOVE The M61A1 Vulcan cannon is located in the right wing root and gives the Eagle its very close range capability.** *(USAF)*

takes him another moment to visually acquire me. I can tell when he does because he rolls out slightly, halting his descent to keep from giving me additional vertical turning room.

Meanwhile I've rolled over on to my back, pointing my lift vector into his six o'clock and pulling 'across the top of the energy egg' (where turns are the tightest and 'God's g' helps you get your nose back down quickly) to sweep down in an oblique circle towards him. 02 responds by pulling up towards me, flying around the larger 'bottom of the egg', working against 'God's g' to get his nose up at me, and we pass again – me diving, him climbing – with me having good, but not good enough, angles at the second merge.

Now that I'm the low guy, I fly around the butt of the egg at best rate, twisting in my seat and craning my neck, straining against the gs as they mount, and catch sight of 02 going over the top above me. I continue pulling up towards him and we approach canopy-to-canopy with me headed uphill, while 02's nose is pointed deep into the water.

Time to change this fight from rates to angles! With 02 headed downhill he won't be able to pull out sharply, whereas I'm over the top at just under corner velocity – I can feel it in the stick. Anticipating the pass, I roll right to point my lift vector deep into his left-turning circle, brace my feet against the rudder pedals and pull the stick all the way to my gut! My Eagle's nose swings round sharply, and as 02 goes zooming past I continue an aircraft-shuddering rolling pull, using a bootful of inside rudder to help roll my jet around into his circle, shedding knots by the butt-load.

Recognising that the fight's changed, 02 pulls hard to get out of his descent, his wings showing great sheets of white vapour, telling me he's desperately deep into the buffet as he rolls towards me. But as our fuselages become somewhat aligned (our noses are now pointed in the same general direction), his downward velocity carries him out in front of me before his upward vector takes him over my canopy bow, rolling for my high six. I respond by rolling underneath, pulling on the tickle towards his low six.

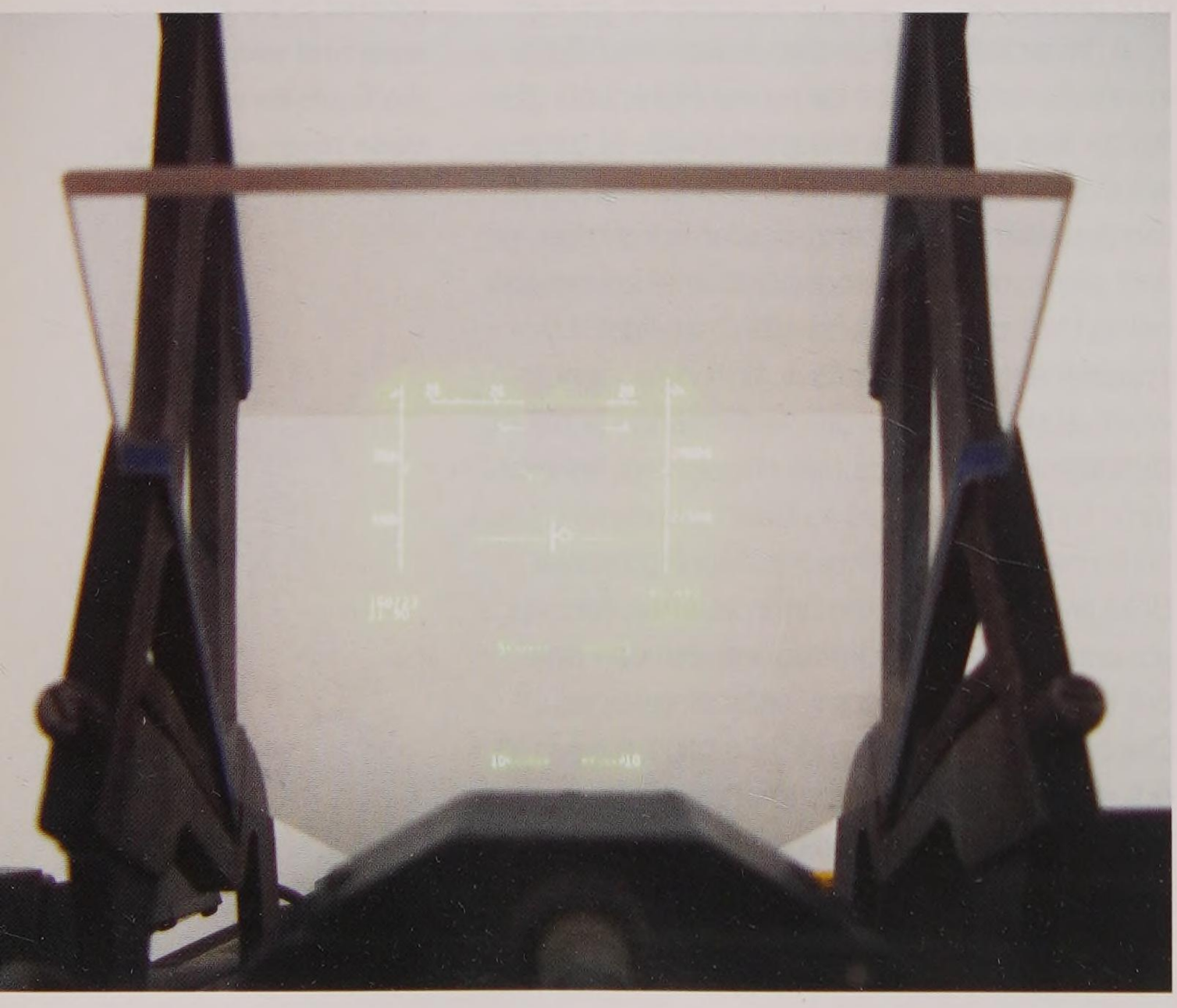
We roll around each other, like two gunfighters wrestling on a saloon floor, our jets horizontally describing two strands of a braid. Although we're both at about 220kt, the descending jet naturally accelerates while the rising one slows, so that the descending one always slides out in front a bit. Known as a 'rolling scissors', this alternating cycle would continue to the airspace floor.

The winner of a 'rolling scissors' is the first one to convert it to a 'flat scissors', so as 02 slides downhill and ahead I set my wings horizontal and give the stick – with both hands now – a sharp, hard pull all the way into my gut and hold it. My Eagle jacks its nose 40–50° into the sky and the whole airframe shudders like there's elephants dancing on the wings, slowing me to 150kt in no time!

I hold it there with both hands, practically standing the jet on its two 25,000lb-thrust columns, making sure I hold the wings level while I watch 02 slide further forward as he attempts to arrest his downhill roll, jacking his own nose up to slow down. But his momentum carries him about 1,000ft ahead of me, at right two o'clock, and I begin a slight bank and use the rudders to walk my nose over to point at him.

Recognising that he is now defensive, 02 unloads dramatically, tipping his nose down, trading the wings' lift for roll authority, and

**BELOW The Eagle's HUD is certified as a primary flight instrument during flying in bad weather. As can just be made out here, pitch and roll steering bars are provided for instrument landing system (ILS) approaches to land.** *(Ben Cook via Steve Davies)*



banks to point his lift vector under my jet, then pulls, going into a slicing turn designed to put me in lag behind him. He crosses beneath my jacked-up nose and, once I make sure he's safely clear, emerging to the left in a 90° banked turn, I shove both stick and rudder into the upper left corner of the cockpit. Unloading and rolling simultaneously, I instantly get light in the seat and shoved to the right as my Eaglet does a sort of pirouette (a dainty concept for a big, 20-ton fighter!) rolling left and rotating the nose down until I'm inverted, nose pointed deep into the water, but on the inside of 02's turn as he's spiralling down, relaxing his AOA to accelerate to better manoeuvring airspeed. This widens his circle, of course, and caring more about nose position than airspeed, I continually roll to keep my lift vector pointed in front of him as I pull out of the ensuing dive, aligning my fuselage with his as I slide out towards his turning circle, saddling up behind him at about 2,000ft.

Now I'm 'highly offensive' (a fighter pilot's usual attitude), and a tracking guns kill is the inevitable conclusion. But we've been at this a long time, so I call 'Check gas' and check my own.

'Two's joker,' meaning he's 200lb above 'bingo' (time to go home). I'm 'Joker plus three' (meaning plus 300lb), so the gunshot ends the engagement as 02 calls 'Bingo, knock it off.'

**ABOVE Another MiG-killer Eagle returns to base following a successful continuation sortie.** *(Gary Klett via Steve Davies)*

## RTB

We rejoin, 'fence out' and begin a military power climb, headed homewards as I coordinate for our departure out of the area and into the recovery corridor. Once we are clear of the airspace, level and cruising home, I call 'Battle damage check' and 02 slides in from tactical to take a close look at my jet, making sure I haven't bent any metal, lost any panels, or sprung any leaks in the hard, even violent, manoeuvring. He passes me to one side and I

**ABOVE Following landing, taxi and shutdown, the Eagle pilot's day is only half over. Infamous in the fighter community for brutal debriefs that go on for hours and leave no stone unturned, F-15 debriefs are a time when rank or experience offer no protection against mistakes being laid bare. It is said that the Eagle community even eat their young...** *(USAF)*

do the same for him, then we settle into a rather relaxed flight back to base and I make a few notes on my line-up card to jog my memory for the debrief.

About five minutes later I hear Scout check out of his half of the airspace and decide that if I slow to 240kt he'll have a mile-a-minute overtake on us and maybe we can come down as we left – as a four-ship. Having a large cambered wing, the Eagle glides smoothly at this speed and we seem to float downhill as we approach the coast and, sure enough, as we're descending through 3,000ft Scout asks permission to join.

'Granted – tactical, one mile trail.'

He cancels his IFR (instrument flight rules) clearance and once again 03 and 04 become an integral part of Eagle flight. I push it up to 300kt.

As we are sent to tower freq, I call for a final fuel check – we're all low, but no one needs preferential priority. 'Tower, Eagle 01, three mile initial with four, tactical.'

'Eagle 01, number one, traffic's a C-130 on six-mile final.'

'Roger.'

We make a 'delayed 90 (degree)' turn on to initial in a tactical container with 6,000ft between jets and, knowing I've got to get 04 on the ground before the 'four fans of freedom' (C-130) gets to two-mile final, I push it up

some more. We go whistling over the numbers (approach end of the runway) at 360kt and I break left, 02 coming with me.

Throttles idle and a hard pull, steadily increasing AOA scrubs off knots by the dozen, and as I roll out 180° later I'm below 240 – gear down, flaps down. Behind me 02 does a 90, hesitates until he clears Scout's nose, then another 90. Scout and 04 follow us. Four Eagles swing through the final turn at 'on speed AOA' (about 170kt) and as I cross the numbers 02's rolling out behind me, Scout's in the turn and 04's just rolling in – Thunderbird spacing.

Throttles idle, nose coming up smoothly, the big Eagle jet squeaks on to the pavement like a Cessna. I hold the nose up to aero-brake (this jet's got no drag chute) down to about 90kt, lower the nose wheel to the runway and coast to taxi speed. I turn off at EOR slowly, allowing the flight to close up to taxi back to the chocks, checking to be sure I'm armed 'SAFE' and shutting off systems according to the after-landing checklist.

After shutdown we log our flying time in the AFTO 781 and visit maintenance debriefing before returning to the squadron for our own debrief.

## Debrief: let the learning begin

The debriefing is where the real learning happens, and we have a myriad of aids to ensure we derive the best benefit from each training experience. Scout takes charge of the two wingmen, grading their shots and cuing their DVRs for the flight debrief, while I telephone the Viper squadron and review the DACT engagement. ACMI will tell us what happened – what I want to know from Viper 01 is what they saw on radar, what bad-guy tactic did they try to execute, and especially what was their impression of the rather confused engagements towards the end of the fight. Viper 01 confirms that there were no TR violations and that they were unable to call any bad-guy kill shots on us. I thank him for providing us with realistic training and promise to return the favour – next time we'll probably be simulating Su-27 Flankers for their DACT training.

We rendezvous at the ACMI debriefing facility, ensure there were no TR violations among us and cover the 'motherhood' – not much needed comment today. Then we begin going through the ACMI-recorded presentation of what happened out there, checking our own formation, debriefed 02 inadvertently hitting the con-layer, and examined closely our radar looks and sorts.

We discussed 02's taking the leaders when his responsibility was normally to target the trailer in the north. Checking his DVR's VSD recording I see that he was presented with what looked more like an echelon formation, where the side-side distance between the Viper groups was about the same as the lead-trail separation – as the guy on the northern flank he felt he had to target their northern-most group to keep them from outflanking us and getting to the imaginary strike package behind us. Since I had not yet defined the enemy groups as 'lead-trail', he was correct to do so, and I make a positive point about his initiative.

Getting into the CAP portion of the mission we check radar looks, commit criteria, engaged tactics and sort out 'who shot John'. ACMI is particularly helpful in making sense of these sorts of confused slugfests – it wasn't pretty, but it was effective: we killed or chased off all challengers for the ten-minute vulnerability time and could declare victory.

Questions? None. We split into separate BFM debriefings and I cover with 02 the three engagements and the shots taken in them. The whole process of debriefing a multi-task mission has been known to take as much time as the original briefing and flight time – sometimes it can be excruciatingly, painfully long and involved. My own limit was that the debrief length should not exceed the flight time for that mission. After that we pass the point of diminishing returns, and learning is increasingly lost in the post-flight exhaustion.

Besides, we need to adjourn to get ready for 'roll call' and 02's naming ceremony, welcoming into our squadron the newest mission-ready F-15 fighter pilot. As the 'Snacko's lackey', 02 is responsible for the keg and shooters, and I certainly don't want to be the one who keeps him from accomplishing his assigned duties!

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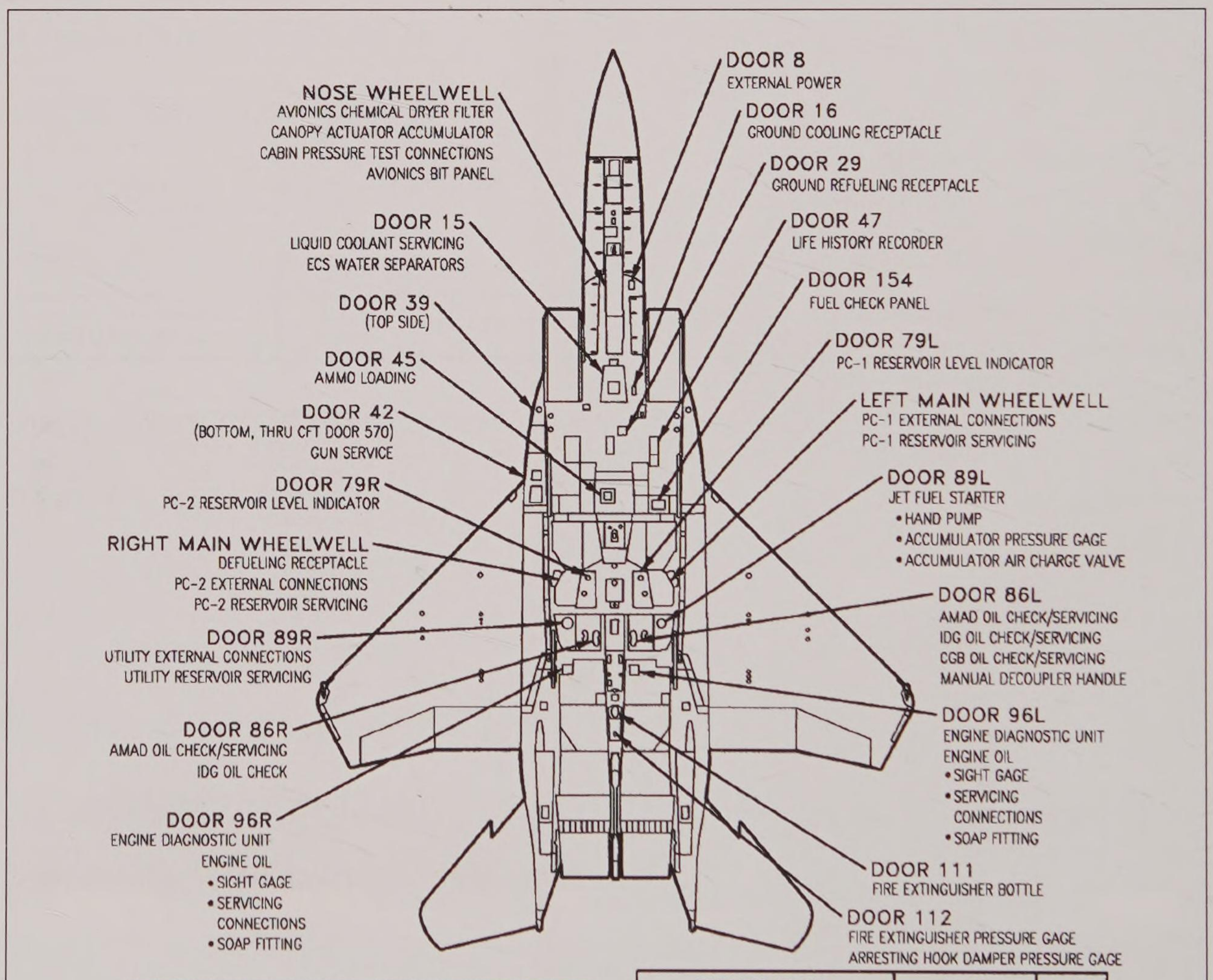
*Chapter Six*

# Maintaining the Eagle: the technician's view

**It is often said that maintainers – those who toil without complaint to keep a squadron's Eagles in the air – are unsung heroes. In truth, it can never be said too often. In this chapter, Master Sergeant Dale Drake, a former Eagle maintainer (now air traffic controller), describes what it takes to keep the world's greatest air superiority fighter in the sky.**

**OPPOSITE A crew chief marshals a fully armed Strike Eagle prior to a sortie.** *(Steve Davies/FJPhotography.com)*

**RIGHT** With remove before flight (RBF) ribbons waving in the wind, and engine intake covers preventing nesting birds or other foreign objects from getting into the engine nacelles, a Strike Eagle sits ready for the arrival of its crew chief. *(Steve Davies/ FJPhotography.com)*




| SPECIFICATIONS | | USAF | NATO |
|---|---|---|---|
| FUEL | PRIMARY | MIL-T-5624,JP-4 JP-8/JP-8+100 (MIL-DTL-83133E) | F-40 F-34 |
| | ALTERNATE (REFER TO SECTION V) | MIL-T-5624, JP-5 JET A, JET A-1, JET B | F-44 F-35 F-43 |
| EXTERNAL ELECTRICAL POWER | 115±15 VAC, 400±30 Hz | A/M 32A-60A ONLY | |
| HYDRAULIC FLUID | | MIL-H-5606 MIL-H-83282 | H-515 H-537 |

| SPECIFICATIONS | | USAF | NATO |
|---|---|---|---|
| OIL | TURBINE ENGINE<br>CENTRAL GEAR BOX<br>INTERGRATED DRIVE GENERATOR<br>AMAD | MIL-L-7808 (NO ALTERNATE) | O-148 |
| NITROGEN | GASEOUS | BB-N-411 GRADE A, TYPE I OR II | |
| OIL | M61A1 GUN | MIL-L-46000 | |
| EXTINGUISHING AGENT | FIRE EXTINGUISHER BOTTLE | HALON-1301 | |

**RIGHT** The servicing diagram shows the location of the main service points on the F-15. *(USAF)*

# Beginnings

It was a hot Texas summer day in August 1998 as I stood behind the thin red line that encompassed the aircraft hangar at Sheppard AFB. Three recent basic training graduates were to my left and three to my right. We stood at parade rest and waited for our instructor.

I have no idea what my instructor talked about that day, whether we were there for five minutes or for an hour; the only thing I can remember is the amazing piece of machinery parked right in front of our group, the F-15 Eagle. I was an 18-year-old kid fresh out of the farms of Kentucky, preparing to take on the maintenance of arguably the best fighter aircraft of all time, and I was in awe of the beauty, power and outright demanding presence of this airplane.

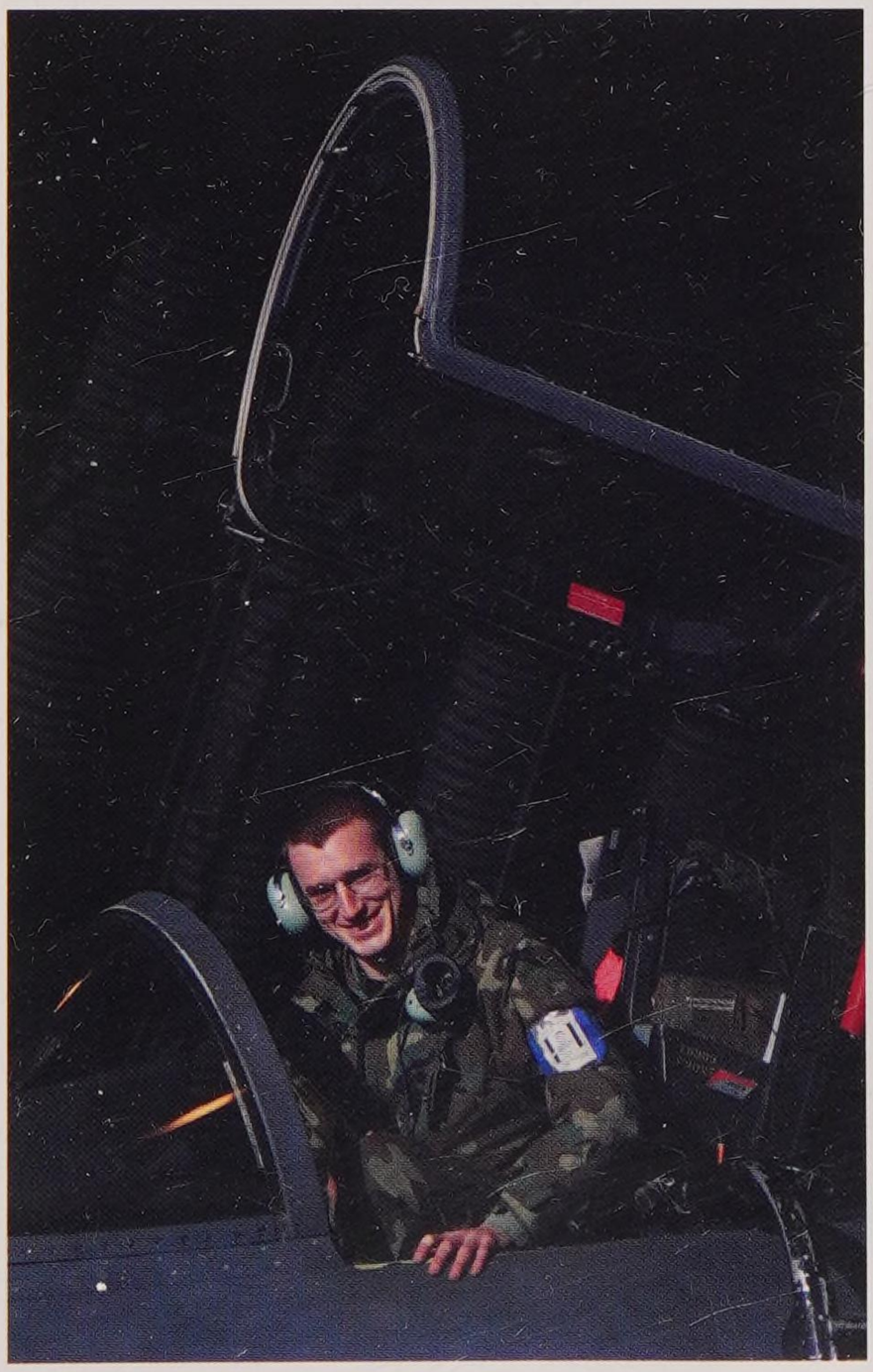
To this day, the smell of jet fuel at an airport with a light summer breeze takes me back to this moment. At technical school you learn the absolute basics of aircraft maintenance and a thing or two about your jet, and then you're off to hands-on training at Tyndall AFB, where you spend a few weeks under close supervision around live Eagles learning launch and recovery procedures.

It's hard to forget that first day that you stepped on to a flightline and heard the whine of a jet fuel starter as the central gearbox disengaged the AMAD and the F-15's engines began to purr and rumble. You can feel the raw and awesome power of the Pratt & Whitney engines as the aircraft taxis out for departure and then screams through the sky on its mission for the day.

I was fortunate enough to graduate from hands-on training and immediately check into Bravo Flight of the 2nd Fighter Squadron, the Horney Horses, that would eventually become the American Beagle Squadron. I was assigned as the 'third wipe' to 83-0015, working under the supervision of the Dedicated Crew Chief (DCC) and the Assistant Dedicated Crew Chief (ADCC). This is where the real work begins, and where you learn to troubleshoot and maintain a complex and dynamic living, fighting beast.

A typical F-15 squadron runs three maintenance shifts and a weekend shift, with some stereotypical differences in what happens during that shift. Your day shift

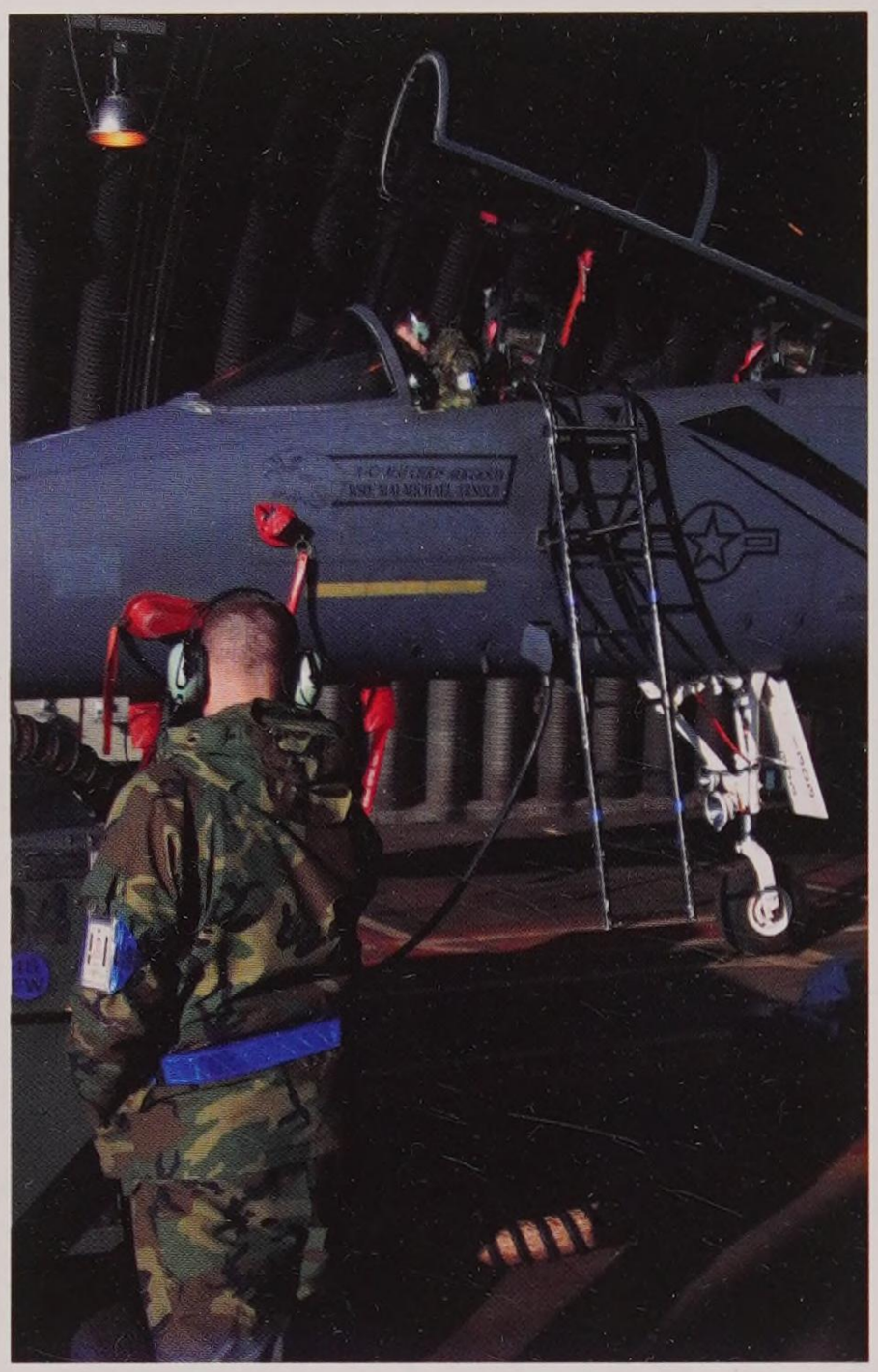
| | AIRSPEED | LOAD FACTOR |
|---|---|---|
| **LANDING GEAR EXTENSION/RETRACTION OR FLIGHT WITH GEAR EXTENDED (Minimize Sideslip)** | 300 KCAS (AIR-TO-AIR WITH OR WITHOUT CFT OR MISSILES, WITHOUT LANTIRN PODS)<br>250 KCAS (ANY CONFIGURATION) | 1.25g<br>2.0g |
| **FLAPS DOWN** | 250 KNOTS | 0.0 TO +4.0g Load factor |
| **INLETS EMERGENCY POSITION** | Above Mach 0.95 | -1.0 to +4.0g |
| **CANOPY OPEN (INCLUDING WIND)** | 60 KNOTS | N/A |
| **TIRES** | NOSE - 210 KNOTS<br>MAIN - 227 KNOTS | N/A<br>N/A |
| SYSTEMS | | |
| **JET FUEL STARTER** | Maximum 10 seconds (15 seconds if temperature below 0°F) between JFS start initiation and READY light. | |
| | Starter engagement time shall not exceed 90 seconds, except if a hot start occurs, the time may be extended to 150 seconds. If the engine engagement time exceeds 90 seconds, wait 20 seconds before again engaging or shutting down the JFS. | |
| | Minimum 10 seconds between first engine at idle speed and engagement for second engine start to allow for JFS stabilization. | |
| **FLIGHT CONTROLS** | To ensure the flight control hydraulic fluid is sufficiently warm before takeoff, observe the listed warm up times for the corresponding temperature range. | |
| | Temperature<br>+4°C (+40°F) AND UP<br>-4°C (+25°F) to +3°C (39°F)<br>-18°C (0°F) to +5°C (24°F)<br>-32°C (-26°F) to +19°C (-9°F)<br>-46°C (-50°F) to -33°C (-27°F) | Time (minutes)<br>No restrictions<br>5<br>8<br>10<br>12 |
| **LANTIRN PODS** | Pods must be turned off above 40,000 feet or if greater than Mach 1.2 or 650 KCAS due to ECU cooling limitations. | |



**ABOVE The limitations that govern the operation of the Eagle, including use of the jet fuel starter.** *(USAF)*

**LEFT In the sun, out of the wind, a Strike Eagle crew chief enjoys a rare spell of good weather at RAF Lakenheath. More typically he can expect rain, wind and low temperatures.** *(FJPhotography.com)*

**RIGHT A 'mule' powers the aircraft while on the ground, and a hose is attached to cool the F-15E's avionics.** *(FJPhotography.com)*



operation is primarily the launch and recovery of jets on their missions.

The swing shift operation typically performs the bulk of the maintenance at the end of the flying day. It gets the jets tidied up and ready for another day of sorties, handing off the leftover maintenance at the end of the shift to a small crew of mid-shifters. These guys take care of the 'admin' work and one or two hard-broke jets.

**BELOW External power is applied via a socket on the left forward fuselage.** *(FJPhotography.com)*

When I say admin work, I mean the daily required tasks of filling liquid oxygen bottles, airing tyres, checking struts, etc. Then there is the dreaded weekend duty that is assigned on a rotating basis for the really hard-broke jets that are scheduled to fly at the start of the next week.

Each of these shifts is important in getting the job done, and most of your maintainers will start out on the day shift. Of course, there are periods where the daily flying window changes to a period of night flying that throws everyone's schedule well to the right and blurs the lines of what each shift does.

## Daily routines

Every day will start with a morning brief from the flight chief, with a status of all the jets: which ones are flying and what their launch times are, which jets are broke, and various other status issues. After the brief, the crews head to the tool shed and start checking out the tool chests and necessary technical orders to begin the day's tasks.

If your jet is slotted to fly, you immediately begin the prep work to make sure it is ready for when the pilots 'step to the jet'. Every crew chief has a different routine that they follow almost like a religion to get their jet ready for the day as they follow the pre-flight technical order (TO). Most start with a quick walk-around looking for any glaring faults or issues that would prevent a safe launch of the jet. You have to check the basics: are the tyres good? Are the JFS accumulators charged and ready? Are there any noticeable leaks of concern? Is a mid-shifter asleep in the intake?

Each crew chief knows the ins and outs of their jet and can tell you every little thing that is or isn't going on, where there are missing screws, how many drips per minute are coming out of the PC1 pump, and on and on. Because of this intimate knowledge of your jet, you are efficient at prepping it for a flight. For whatever reason, if you had to crew another jet the time it takes to get it ready increases significantly, as you have to examine every step of the technical order to make sure you don't miss anything. Typically, though, you'll stay on your own jet.

Once you finish your pre-flight inspection, the

waiting game begins, depending on the slotted flight time. If you have time, you go assist the other members of your flight in getting their jets prepped, or tinker around with whatever maintenance is going on. Some crew chiefs will spend this waiting time cleaning and polishing their jet like it's their very own hot rod. I once had a flight chief who would always say 'A clean jet is a happy jet, and a happy jet flies code 1!' More on that later.

About half an hour before the flight crew steps to the jet, you'll start taking all the 'dash 1' gear off it. Dash 1 gear is all the items that cover or protect the aircraft's sensors, antennas and intakes while it's on the ground. This includes the pitot tubes, jet intakes and exhaust vents.

At some point in this morning ritual, the production superintendent will come by and review your aircraft forms binders to make sure that all the maintenance has been accomplished, documented and certified complete. They'll look at where the aircraft is in the phase maintenance schedule, make sure no preventative maintenance has been overlooked, maybe ask you a couple of questions, and then sign off the 'exceptional release' that allows your jet to fly. Now you're ready.

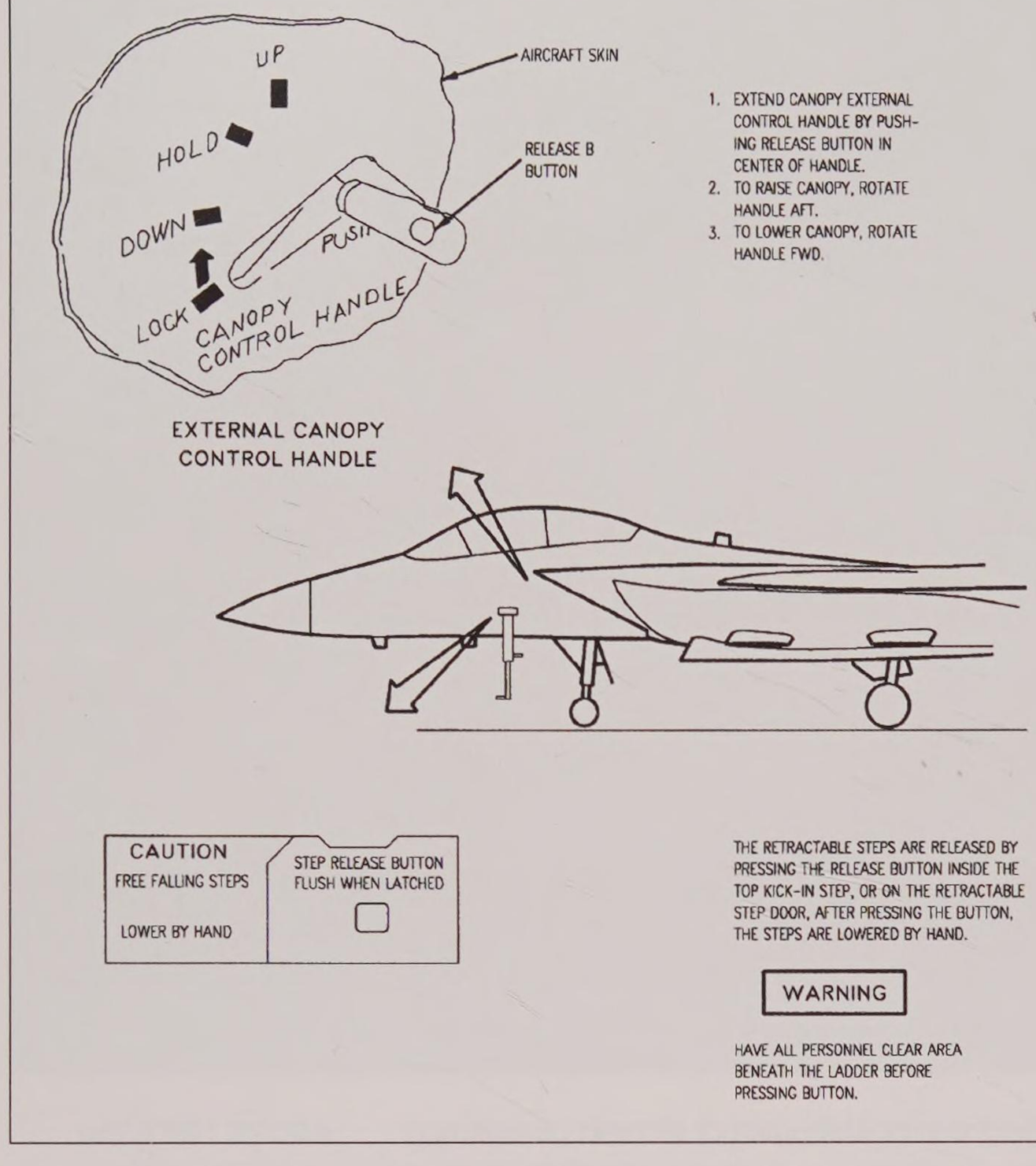
As the pilot steps out of the van geared up for their mission, you welcome them to your jet with a sharp salute and then get straight to business. You take the pilot's helmet and flight bag to the cockpit, then start unsafing the ACES II ejection seat by removing all the pins that keep everything in place.

While you're getting the cockpit set up, the pilot will glance at the forms and then perform their own walk-around of the jet. They might also ask a couple of questions. I never had a pilot find anything on their walk-around. I did, however, have a student pilot actually kick the tyres once like he was checking the pressure, which made me chuckle. Even if that tyre didn't have the 360psi that was required, the kick of your boot will reveal nothing more than you just kicked a steel-belted super-tyre designed to help absorb the impact of a 30K-pound jet impacting a runway at 160kt. And, even if it was completely flat, it wouldn't flex.

When the pilot is ready, they connect up the last clips on their life support equipment and climb into the jet, almost always via the crew boarding ladder. (The jet has a built-in ladder system that is rarely used.) You follow the pilot up the ladder and help hook them into the

**ABOVE LEFT The crew chief follows a pilot on his walkaround, providing additional historical and technical expertise and information about 'his' jet to the man who is about to 'borrow' it.** *(Steve Davies/ FJPhotography.com)*

**ABOVE Buttoning-up panels and removing safety pins leaves the F-15 pilot free to concentrate on his critical pre-flight walkaround.** *(Steve Davies/ FJPhotography.com)*


UP
HOLD
DOWN
LOCK
CANOPY CONTROL HANDLE
AIRCRAFT SKIN
RELEASE B BUTTON
1. EXTEND CANOPY EXTERNAL CONTROL HANDLE BY PUSHING RELEASE BUTTON IN CENTER OF HANDLE.
2. TO RAISE CANOPY, ROTATE HANDLE AFT.
3. TO LOWER CANOPY, ROTATE HANDLE FWD.
EXTERNAL CANOPY CONTROL HANDLE
CAUTION
FREE FALLING STEPS
LOWER BY HAND
STEP RELEASE BUTTON FLUSH WHEN LATCHED
THE RETRACTABLE STEPS ARE RELEASED BY PRESSING THE RELEASE BUTTON INSIDE THE TOP KICK-IN STEP, OR ON THE RETRACTABLE STEP DOOR, AFTER PRESSING THE BUTTON, THE STEPS ARE LOWERED BY HAND.
WARNING
HAVE ALL PERSONNEL CLEAR AREA BENEATH THE LADDER BEFORE PRESSING BUTTON.

**ABOVE With the pilot strapped in, the crew chief stands ready to start.** *(Steve Davies/ FJPhotography.com)*



**ABOVE Entry into the cockpit is via an external ladder or these retractable internal steps.** *(USAF)*




**RIGHT A maintainer prepares the cockpit while the crew chief talks through the forms with the pilot.** *(Steve Davies/ FJPhotography.com)*

**FAR RIGHT The crew chief will help the pilot strap in and ensure that all is OK before climbing down and removing the external ladder to allow engine start.** *(Steve Davies/ FJPhotography.com)*

**LEFT Yellow fire extinguishers stand ready, manned by fire guards who will attempt to put out any flames should the start process go bad.** *(Steve Davies/ FJPhotography.com)*

ejection seat, grab any loose items and then remove the canopy support brace that kept the canopy from closing if its actuator had lost its hydraulic pressure overnight. You'll set these items aside, connect up your comm kit, make sure your 'B man' (the person assisting the crew chief) is ready by the fire bottle, and then stand by to the pilot's left.

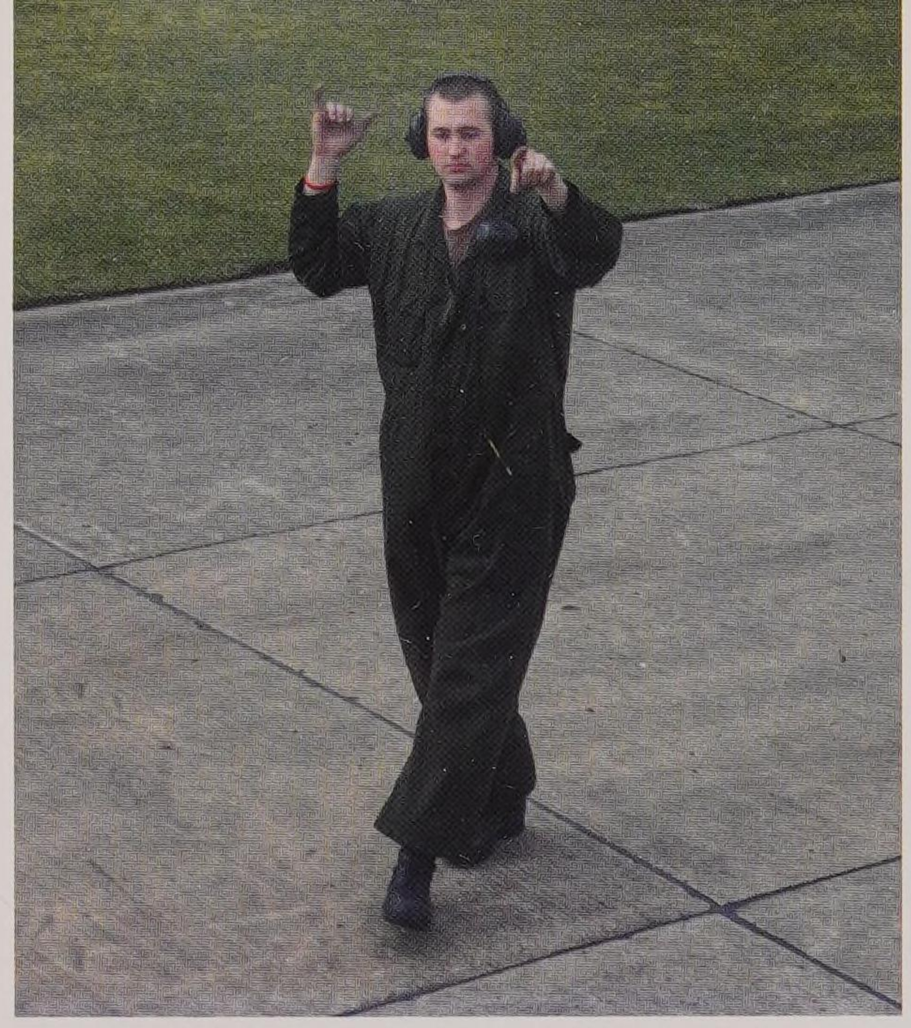
When they're ready, they give you a hand signal that looks like the 'come here' sign, but with two fingers. This means they are ready to pull the handle on the JFS accumulators and initiate the starting sequence. Last look around, all's good, you repeat the signal and the pilot pulls the handle. Hydraulic pressure rushes out of one of the two accumulator bottles and starts spinning the JFS until it reaches a point of self-sustainment. This is the point in the starting sequence that you are most likely to have a fire. That is the main purpose of your B man, who stands by the Halon fire extinguisher ready to jump into action if it all goes wrong. Fortunately, it is extremely rare that anything goes wrong – this is due to the exceptional maintenance schedule and professionalism of those that work these airframes.

It's an unforgettable sound, as the tiny jet engine whines up to full power. Once the JFS is running, you do a quick communications check with the pilot and then they request to start engine No 2, which is on their right side. If nothing is wrong at this point, you approve and they initiate the start on No 2.

The JFS picks up speed and starts turning the central gear box (CGB), which engages the airframe-mounted accessories drive (AMAD) via a pawl carrier. The rotational forces are transferred through the AMAD, which spins the hydraulic pumps and the integrated generator (IDG) and out its backside to a PTO (power take-off) shaft connected to the engine. Once the jet engine gets up to a self-sustaining speed, the CGB automatically disengages and the Pratt & Whitney takes over running all the subsystems. The JFS also disengages, belting out a whirring noise and slowing back down to idle.

Once the engine is up and running, hydraulic pressure runs through the jet and brings systems to life. It is now safe to remove the aircraft landing gear safing pins, as 3,000psi of hydraulic pressure is now ensuring the gear stays in the correct position, and the weight-on-wheels switch that prevents landing gear retraction now has electrical power.

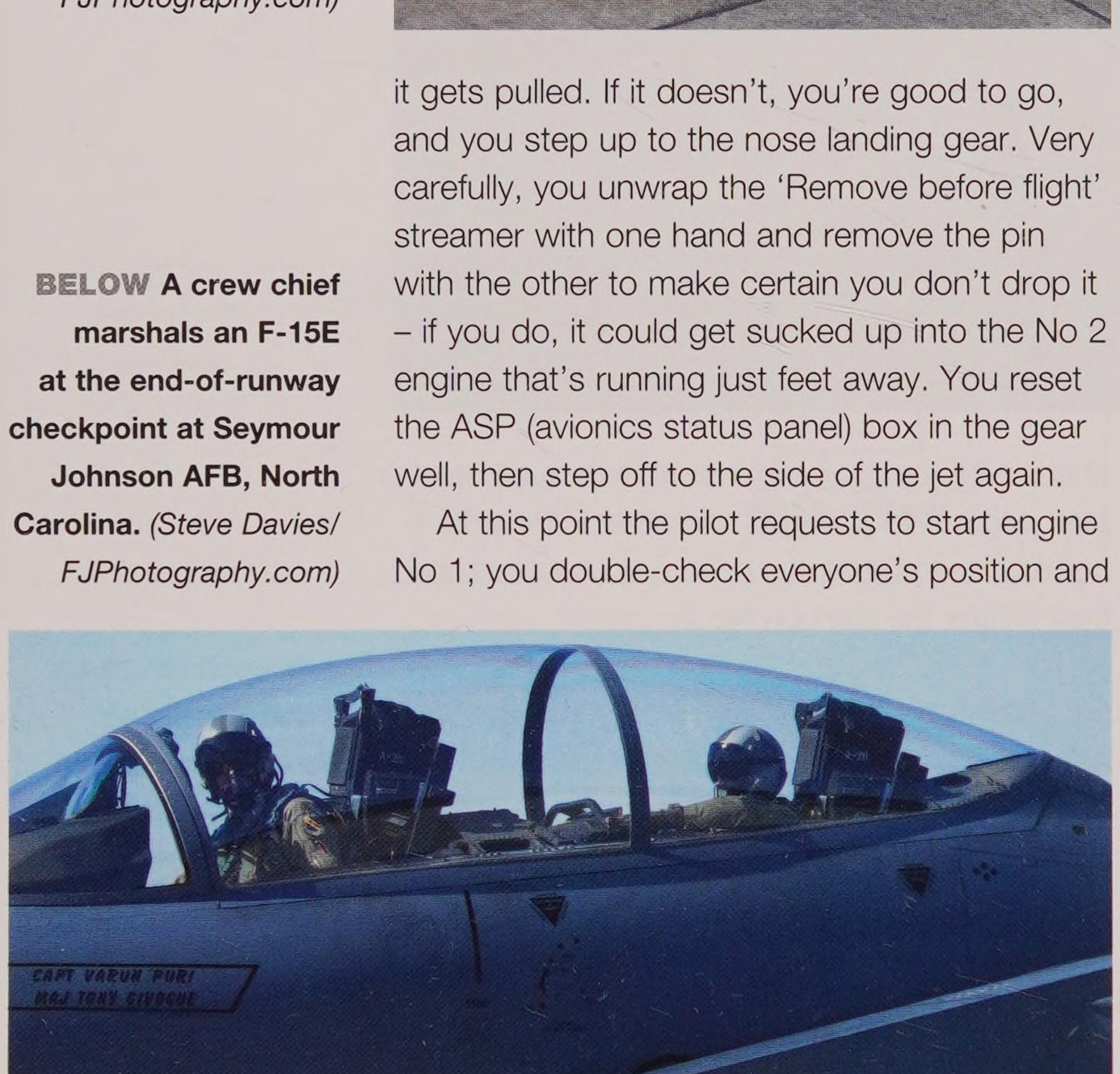
Prior to starting the No 1 engine, the crew chief will walk up the side of the jet, and double-check the No 1 engine isn't running by placing his hand near the lip of the intake and seeing if



**RIGHT A crew chief at RAF Lakenheath marshals a 493rd FS F-15 out of its chocks. The coveralls provide an appropriate level of protection against the chemicals and grime that the Eagle maintainer comes into contact with daily.** *(Steve Davies/ FJPhotography.com)*

it gets pulled. If it doesn't, you're good to go, and you step up to the nose landing gear. Very carefully, you unwrap the 'Remove before flight' streamer with one hand and remove the pin with the other to make certain you don't drop it – if you do, it could get sucked up into the No 2 engine that's running just feet away. You reset the ASP (avionics status panel) box in the gear well, then step off to the side of the jet again.

At this point the pilot requests to start engine No 1; you double-check everyone's position and




**BELOW A crew chief marshals an F-15E at the end-of-runway checkpoint at Seymour Johnson AFB, North Carolina.** *(Steve Davies/ FJPhotography.com)*

give approval. The same process repeats itself with the CGB and AMAD until the No 1 engine is self-sustaining. The moment it is, you see the intake ramp drop from the full upright position, which is your visual indicator to get to work while the pilot runs through some checks of his own. You'll go around removing the remaining safety pins in the gear, check the hydraulic pressures on PC1, PC2 and the utility system, button up those panels and start observing for anything out of the norm, like leaks or smoke.

About the time you finish up the pilot will be ready to start checking the flight control surfaces, beginning with the flaps and speed brake. I always started on the right side of the jet to watch the flap drop, grabbed it to make sure it locked down, ducked underneath the jet waving my hand under the JFS exhaust to double-check it wasn't running, and then checked the left flap. Finally I took a last look up at the top to make sure the speed brake fully extended and then retracted. Then you step around the rear stabilators and check their functionality as the pilot cycles them through both tips up, both tips down, and alternating. Finally the pilot will cycle all of the flight controls simultaneously to make sure everything is working and that it is working together as you visually observe and track the movements of the ailerons, rudders and stabilators.

You're pretty much done at this point and just ask for a heads up a few minutes before the pilot is ready to taxi. You go around and double- and triple-check that everything is secure, the right safety pins have been removed, and all of your tools are accounted for. Some of them will remain in the jet until the end of runway inspection. You stash all the pins in a bag and place them inside the jet's storage area on the bottom side.

When the pilot's ready, you disconnect comms, button up the panel, roll up and store your comm cord and then step out in front of the jet at the pilot's 11 o'clock position and assume the position of parade rest. The pilot gives you the hand signal for removing the chocks when they are ready to taxi. You repeat the signal to your B man, who kicks the chocks out and then gets off to the side clear of the pending jet blast. While they are doing this you hold your arms in an X over your head to indicate to the pilot to

hold the brakes and wait for your command.

Once your B man is safely to the side of the jet, you double-check the taxi path and then give the pilot the 'run 'em up' signal by extending the thumb and pinkie on your right hand and shaking them while pointing at the jet with your left hand. The pilot will bump the throttles up and, as the jet starts to move, you transition to marshalling the jet out of its parking spot. As the aircraft passes your position, you snap a sharp salute. The pilot returns the salute and it's over: your jet is headed out to the fight. I'd always jump up and bump the wingtip with my fist as the jet passed overhead – a superstitious habit!

I don't care how many times you go through this take-off routine, that moment when you snap a salute to the pilot as your F-15 taxis past was awesome, and made my adrenaline pump.

Now that the jet is taxiing out, you take the time to again check all your gear and make sure everything is secure. Then you stand by while you wait for your jet to depart. Sometimes in EOR something would malfunction and require on-the-spot maintenance. It was typically an avionics issue that was fixed on the spot, but sometimes your jet would have to return to parking to get repaired or to shut down for major repairs. Once your jet is airborne it is time to eat or pitch in on other maintenance happening on the line or in the hangar. Then you wait for your jet's return.

Most of the crew chiefs gather in the expeditor truck to grab some chow and hang out while waiting on Ops (the squadron operations desk, which is in contact with the Eagle pilots) to call back with the jets' status and estimated return time.

## Recovery

After each mission pilots will rate the jet Code 1, 2 or 3. Code 1 is no deficiencies; Code 2 is some sort of minor issue; and Code 3 is a broke jet that requires maintenance before its next flight. This is indicated by placing a red 'X' in the maintenance records along with a description of the issue. You obviously shoot for a Code 1, but those were the rarest, especially if your pilot had a rough training session.

These codes were tracked, along with tons of other statistics on your jet, and the number

## F-15 EAGLE PRODUCTION AND VARIANTS (TO APRIL 2014)

**McDonnell Douglas Aircraft Corporation (McAir) – now Boeing**

| Version | Quantity | Assembly location | Time period |
|---|---|---|---|
| F-15A | 384 | St Louis, Missouri | 1972–79 |
| F-15B | 61 | St Louis, Missouri | 1972–79 |
| F-15C | 483 | St Louis, Missouri | 1979–85 |
| F-15D | 92 | St Louis, Missouri | 1979–85 |
| F-15E | 420 | St Louis, Missouri | 1985–present |
| F-15J | 2 | St Louis, Missouri | 1979–80 |
| F-15DJ | 12 | St Louis, Missouri | 1979–81 |
| **Total** | **1,454** | | |

**Mitsubishi Heavy Industries Ltd**

| Version | Quantity | Assembly location | Time period |
|---|---|---|---|
| F-15J/DJ | 139/25 | Tokyo | 1981–97 |
| **Total** | **164** | | |

**ABOVE The arms crossed signal means that the pilot should apply and hold his toe brakes.** *(Steve Davies/ FJPhotography.com)*

of sorties and Code 1s that your jet had could put you in the running for the Wing Top Flyer award. This was a badge of honour, and I was proud to get it a few times. I set a personal best with 42 Code 1 flights in a single month; just shy of the Wing record.

Typically, jets were slotted for two flights a day. Those that returned Code 1 got a 'Thru-Flight' inspection and repeated the cycle. Code 2 jets typically got their minor issues fixed and signed off and repeated the cycle as well. A Code 3 jet more often than not wouldn't make its second flight due to the required maintenance, and the squadron would shift that sortie to a spare aircraft that had been on standby.

Recovering a jet is a pretty straightforward process. You marshal the jet into its parking spot, stopping the pilot about two feet in front of the final spot so that the B-man can check the main tyres for FOD (foreign objects) or damage, roll the jet forward that last two feet and check the tyres again, checking the tyre patch that had been on the pavement. The B-man chocks the tyres and you connect the comm chord and start a quick debrief with the pilot.

Sometimes you can sort out any minor errors on comm with some switchology, but more often than not you are looking for a description of how the jet performed and what you can do to make it better. During this process, you put the ground safing pins in the main gear, check all the hydraulic pressures, look for leaks, cram two pieces of PVC pipe into the fuel drains of the engines, and then let the pilot know it is safe to shut it down.

When the engines shut down, about half a gallon of jet fuel will collect in both of the PVC pipes. You transfer this to a bucket and dispose of it at the end of the shift. At this point, you put the crew ladder on the jet and go assist the pilot in disconnecting, gathering their bags and safing the ejection seat.

The pilot will do a walk-around and continue their debrief while you take oil samples and begin your work. When all this is done, you give the pilot one more salute and they head off in the Ops van while you get to work prepping your jet for its next flight, or bedding it down for the night, depending on the schedule.

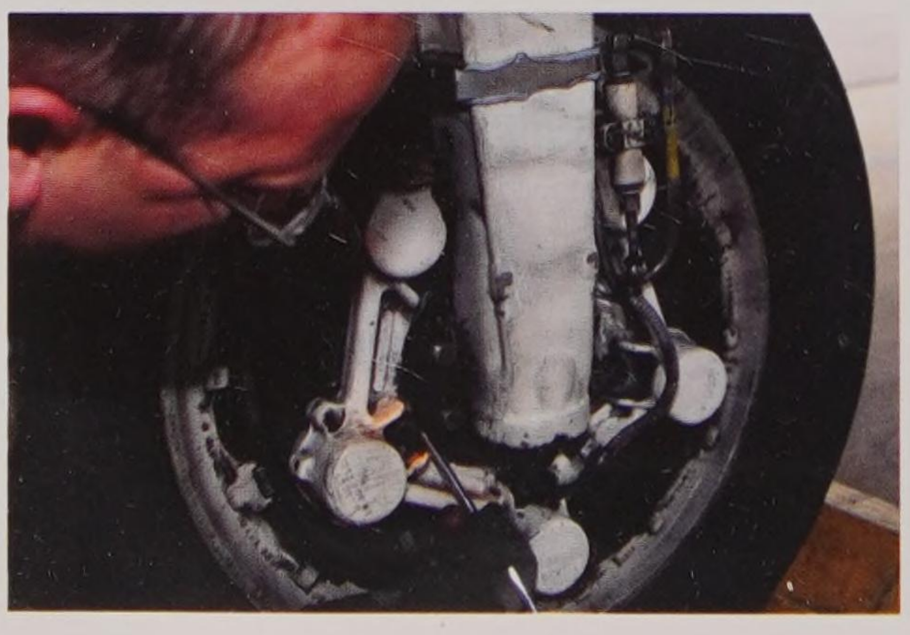
On 'Surge' days your jet could fly three to five times through the day, with what's called a 'Quick-Turn' inspection between flights that basically checks for pouring leaks and giant holes in the jet. More often, though, you do a 'Thru-Flight' inspection, which is more in-depth. At the end of the flying day you do a 'Basic Post-Flight Inspection', which is extremely thorough and is designed to fully evaluate the jet's condition and flyability for the next day.

## Swing shift

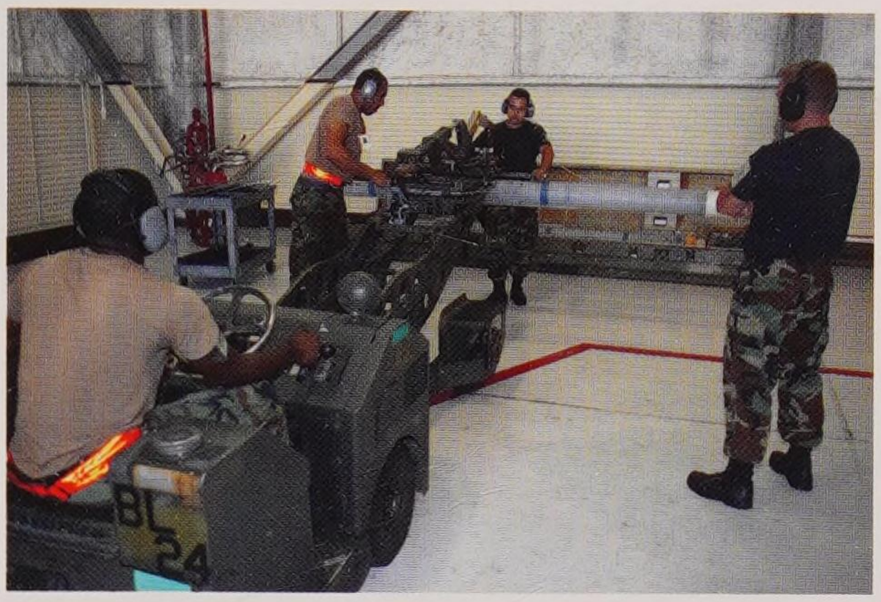
After the second flight of the day, it is typically time for the swing shift to start their day. I spent my first two months working day shifts, getting the launch and recovery procedures down, but was fortunate enough to head to swing shifts fairly early for a new guy.

I was also bumped up to the role of ADCC.

**RIGHT A maintainer inspects the brakes for leaks and wear following another successful sortie.** *(Steve Davies/ FJPhotography.com)*



**FAR RIGHT Checks to the JFS pressure levels are also made.** *(Steve Davies/ FJPhotography.com)*



**FAR LEFT Weapons troops have to arm and de-arm the aircraft between sorties. Here a crew practise loading an inert AIM-120 AMRAAM missile.** *(FJPhotography.com)*

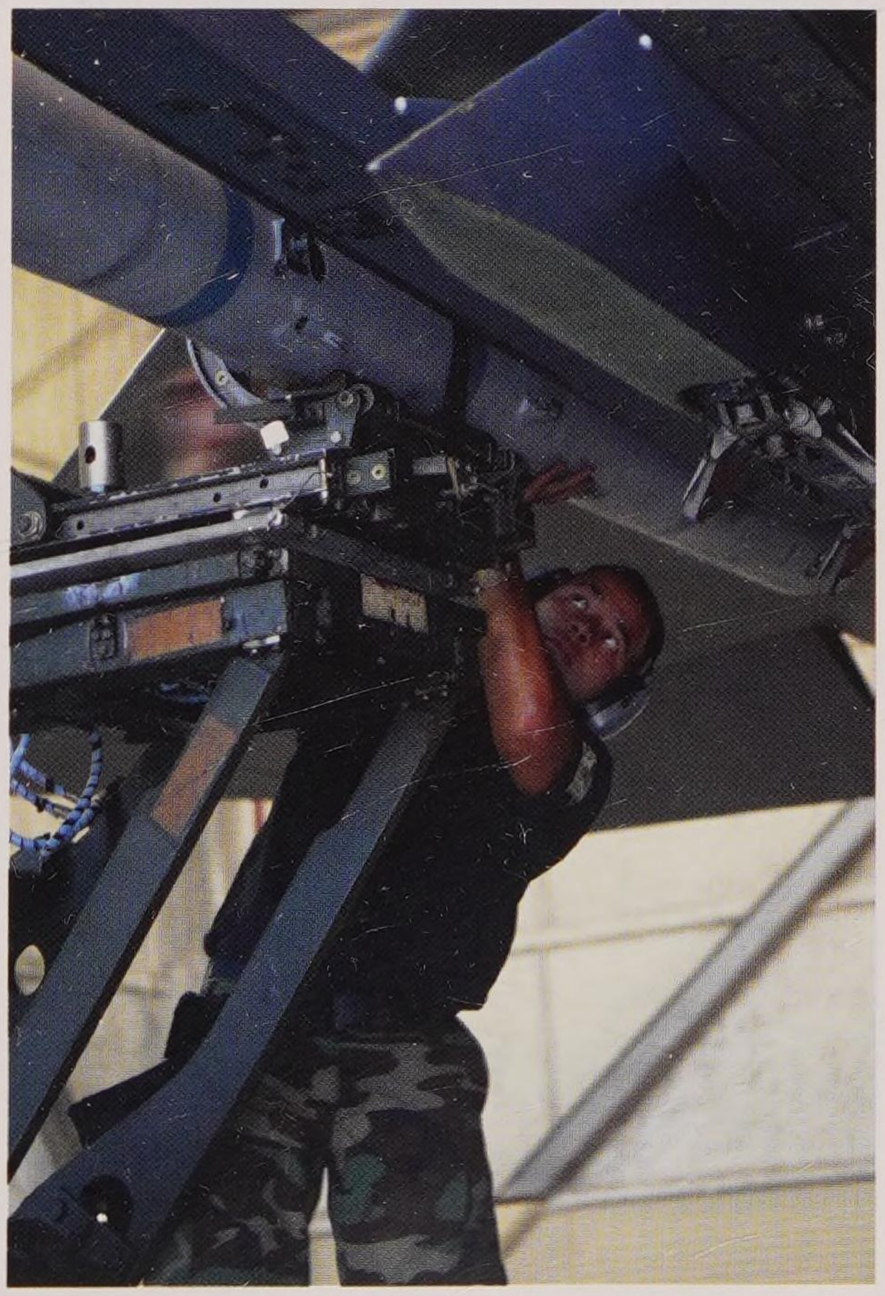
**LEFT A 'jammer' loading vehicle is used to do as much of the lifting as possible.** *(Steve Davies/ FJPhotography.com)*

**FAR LEFT AND LEFT The crew must use skill to ensure proper alignment of the missile and the rail on to which it will be attached.** *(Steve Davies/ FJPhotography.com)*

This was huge, because as the ADCC you got your name on the jet. I remember to this day sending those pictures of my name on this war fighter back to friends and family as I beamed with pride.

The mentality is entirely different on swing shifts and is focused on prepping the jets for the next day's sorties. The majority of jets that fly one or more sorties in a day come back with a known discrepancy or a deficiency that is identified in the 'Basic Post-Flight Inspection'. They therefore require maintenance to be ready for the next day.

A typical squadron has about twenty jets, with about ten jets in each flight. For us in the 2nd, Alpha Flight was the front row of jets and Bravo Flight was the back row. Some of your jets would have no issues and could be buttoned up within a few hours of its last flight. However, out of the ten jets within your flight's control, 90% of the time a few jets would be hard broke and the team would be there for 10–14 hours getting them 'greened' up.



**LEFT A final shove and the missile is in place.** *(Steve Davies/ FJPhotography.com)*

There were a variety of issues that required different specialists. A typical fighter squadron (maintenance was in the flying squadron at this point of my career) would include avionics, weapons, jet engine mechanics, structural repair and, of course, crew chiefs. Each trade had responsibility over certain systems, while the crew chief was responsible for the entire operation on their jet.

Most days would involve avionics specialists, or 'pointyheads' as we called them, doing some troubleshooting or box-swapping near the nose of the jet. These folks were incredibly smart in their systems and invaluable in keeping those critical systems up and running. A weapons crew, which consisted of three people, would come around and address any issues with the weapons systems, such as removing/replacing missiles, pylons, explosive charges in the pylons or even working the gun system from time to time. You never saw them in groups of less than three, and this led to many hypotheses as to why.

## Engine runs

The assistance of a jet mechanic wasn't needed as often, but if you needed their help you were in for a long night of engine runs to troubleshoot, or removing and re-installing (R&R)

**RIGHT A drop-down control box under the left engine nacelle gives the maintainer access to a range of system tests.** *(FJPhotography.com)*

a new engine. The R&R process involved a much loathed engine bay inspection that required a team to evaluate every rivet, every surface, every rib and every wire in the entire bay. There was no room for error. After a journeyman completed the inspection, a more experienced crew chief – a craftsman – would double-check the work as well, before finally Quality Assurance would come and do a tertiary inspection before the new engine could be slid back in on rails, connected and tested. Oddly enough there are only three mount bolts that hold the engine in, and then it's just a matter of connecting the PTO shaft, the fuel line and a few wires.

Most work that was done to the engines required a live engine run by the ground crews to test it out. The runs were either accomplished right there in parking, on the trim pad if an afterburner run was required, or in the 'Hush House' if extensive diagnostics were required.

The trim pad was a nearly complete circular wall that angled the jet blast up at about 45°. The jet's arresting gear was lowered and connected to a massive hook and the tyres were double-chocked to contain the nearly 60,000lb of thrust. There is no feeling quite like sitting on the throttles of an F-15 in full afterburner, stationary on the ground. It's terrifying and exciting. It's also an incredible feeling to be standing just feet away from the afterburner on the ground, especially if there was an AB blowout. The power of the jet resonates through your body and damn near cleans out your sinuses as it rattles your insides relentlessly.

Then there is the Hush House. This is a state-of-the-art engine diagnostics facility where you connect the jet up in the same way as the trim pad, but inside a hangar that barely fits the aircraft and to a control room on the side of the hangar. There is a giant exhaust pipe that runs out the back of the Hush House and directs the blast out and up.

Due to the precise location requirements of the jet within the Hush House – the exhaust must go directly down the pipe – the crew chief team had to perfectly park the jet in the facility. Putting a jet into the Hush House accurately on the first try was one of many games we played on the flightline, and only the best tow drivers could accomplish this.

When pushing a jet backwards the tow truck

faces the jet and is connected to the nose gear by a tow bar. You have to account for and manipulate all three pivot points, which is a skill that some people never really mastered while others were just naturals at it.

Each of these specialists were critical in keeping your jet flyable and ready to accomplish its mission. There is a lot of playful rivalry between the specialties on the flightline, but in the end the jet wouldn't be able to accomplish its mission without each of them.

## Long nights

Although no night was typical on a swing shift, reflecting back on my time it was hydraulics that kept us there late most often. The F-15 utilises three hydraulic systems: Power Control 1 (PC1), Power Control 2 (PC2) and the utility system. Each system is run by a pump mounted on one of the AMADs, with the utility system having two pumps, one on each AMAD. It wasn't uncommon to have to change these pumps if the pressure was off or if it was leaking outside of limits.

The pump itself was simple but one part of the install was notoriously challenging: you had to line the drive gear splines up with the splines in the AMAD and wiggle the pump in. Sometimes it would slide right in and other times you would push, shove and cuss for an eternity, only for another crew chief to walk up and slam it in first try!

These AMADS, hydraulic pumps, electric generators, JFS and CGB are all lumped together and called the secondary power system and, in my opinion, accounted for most of our work.

Outside of these systems, typical issues included the hydraulic reservoirs for each system that could be finicky, flight control actuators or random hydraulics lines that would leak or burst, each buried and tangled in its own special way deep inside the jet. Some may consider it odd, but I enjoyed the complex work that came with finding these issues and then fixing them. I was fortunate in my experience that my first few months on swing shift exposed me to some major system failures that sharpened my skill set, such as AMADs, JFS/CGBs and utility reservoirs.

Crew chiefs were arrogant about their own prowess on the jets and we would often try to

**ABOVE Three jacks are all that are needed to support the weight of a Strike Eagle.** *(Steve Davies/ FJPhotography.com)*

set time records in completing these tasks, a sort of crew chief Olympics if you will.

One of our favourite competitions was how fast a team of two could R&R a JFS. Time started when the first speedhandle touched the panel and stopped when the last piece of safety wire was cut on the dog ears. The entire time was trashed if those dog ears weren't safety-wired exactly to specs, which was a challenge because they were jammed deep inside the jet and often challenged the most experienced crew chief. I can't recall the exact time, but I believe the record was impressively under ten minutes.

R&R of a utility reservoir was not a simple process by any means, though, and there was no race in this process. It involved multiple panels coming off so you could access the reservoir from under the jet and to the side as well. As with most components, the reservoir itself was buried in a tangled web of titanium hydraulic lines that had to be removed and untangled.

The challenging part was the installation, as you had to recall where each of the twisted hydraulic lines originated and where it went. You would often put one line in only to find that it was blocking the install of another line, and no two installs ever seemed to go the same way. Once you had sorted out all the lines and clamps and double-checked that each mounting bolt was properly torqued, as well as having the correct number of washers, spacers or bushings, it was time to test out your work. In this case that would require hydraulic and electrical power so that you could pressurise the system and check for leaks. As you did this, a second member sat in the cockpit and monitored pressures.

While this was all challenging, the most difficult component that I ever had to replace was the emergency generator selector switch valve (EGSSV). You accessed this from the top of the jet, just below the emergency hydraulic generator. It sat about two to three feet down from the top and was more than buried; it was encased. We joked that the EGSSV was hung from the rafters and that the entire jet was built around it. Either that or there was some indiscretion by a crew chief and an engineer's family the night before the F-15 was designed.

## AGE – aerospace ground equipment

Whether it was the AMAD, a hydraulic reservoir or the EGSSV, each repair required ground testing, which in turn required some sort of power being applied to the airframe.

Such ground testing of systems involved any combination of the jet's life-support equipment, or aerospace ground equipment. The three main pieces were the 60 electrical cart, the hydraulic mule and the air cart.

The 60 was about half the size of a normal car and contained a jet engine that supplied power to the jet via a giant electrical cord that plugged into the F-15 near the nose gear. The hydraulic mule was a larger piece of equipment with the capability to supply hydraulic pressure to all three systems at once. The air cart basically duplicated the bleed air system of the jet to work on certain E&E (escape and evasion) systems. Other smaller pieces of AGE included the oil and hydraulic carts, stands that helped you reach places on the jet, lighting systems and even heaters.

## Midshift

The swing shift will work until the work is done and the fleet is ready for the next day's sorties, only turning over one or two broken jets to the midshift, but not before addressing the dreaded paper trail that is generated by aircraft maintenance.

Each jet has a set of forms that meticulously documents every bit of maintenance that happens on the jet, and these forms have to be addressed every single night. All the jets that are ready for the next day have their forms binder signed off and tucked away for the next day. All others are turned over to the midshift, which typically has only a handful of maintainers from each specialty.

While I loved all that I got to do and learn while on the swing shift, midshifts were a nice break from the long hours. I had my tasks laid out for me at the beginning of the night and could just get to work without much interference. There weren't crowds of maintainers, there were no officers floating around, there was very little management, and you didn't have an expeditor coming by to check your progress and crack the whip. You could just work on the jet and get the job done.

The midshift would finish up any maintenance that the swings hadn't accomplished, and then do a lot of the administrative tasks of the flightline such as servicing struts and towing jets to and from various hangars for different types of maintenance.

Most of the time the midshift handed over a mission-capable fleet to the day shift, but there were always those days that a jet stayed broke for days and kept getting kicked around.

## Phase

There are other aspects to flightline maintenance outside of the folks launching, recovering and repairing jets. Each jet will cycle through other stages that will take it and its crew chief off the line. After a set period of flying hours the jet will enter phase maintenance within the unit.

Phase maintenance is an extensive inspection of the entire jet that takes about a month. The phase team will disassemble and inspect the majority of your jet, looking beyond the superficial leaks and drips.

A large part of the phase inspection inevitably ended up being structural repairs due to hairline cracks resulting from the relentless abuse of g-forces, landings and take-offs.

The structural repair specialists did a lot of hard work during the phase inspection of jets, beyond all the assistance provided on the line. The worst thing that could happen was for your jet to become the 'cann' jet, short for cannibalisation. Sometimes it was scheduled and sometimes it was out of necessity, as your jet was already broken, and if an operational jet needed a

**FAR LEFT In phase maintenance, much more thorough inspections are undertaken.** *(Steve Davies/ FJPhotography.com)*

**LEFT Avionics troops repair and maintain the LANTIRN equipment for the Strike Eagle. Here an AAQ-14 target pod is opened up, and black boxes have been pulled for troubleshooting.** *(Steve Davies/ FJPhotography.com)*

component and the supply chain did not have it immediately available your jet would donate the part. This cannibalisation usually lasted about a month and involved extensive work to get it mission-capable again afterwards, but it was a necessary evil in maintaining the health of the fleet.

Then there were short stops like the paint shop, washrack and fuel barn. The entire fleet was a well-oiled machine on a constant cycle through all these different phases of maintenance so that, in the end, you could generate enough jets to meet the flying demand each and every day.

## A family bond

As I look back on my time as an F-15 crew chief, I value and appreciate the times out on that flightline. Through the blazing heat, pouring rain and blistering cold, I developed a family-like bond while working on these amazing aircraft. You make some of the best friends you'll ever have, and, of course, you'll encounter other people that just constantly get on your nerves – just like any family!

You'll spend much of your time with these people, towing jets around, running ground tests, troubleshooting, and just elbows-deep in hydraulic fluid and a pile of parts figuring out what the hell is going on and why your jet is producing a particular bizarre error – all the time getting to know and respect each other personally and professionally.

Looking back on these times on the flightline, I think about the occasions when we would randomly grab folks and duct tape them to any surface or person nearby and leave them for their team to find. I remember the two-week temporary duty visits to places like Vegas, Luke or Key West Florida, where I lost my flightline drivers' licence for popping wheelies on a Navy tug. And I remember the late nights where we would play rock, paper, scissors to determine who would sign off the forms. These were among the highlights of my career in the United States Air Force.

It was the crusty old flightline NCOs and SNCOs (senior NCOs) turning wrenches, leading and mentoring that developed me and are directly accountable for any successes I've achieved since leaving that flightline. They instilled in me a sense of pride in what we accomplished and a work ethic that is unmatched in many other career fields. As a kid fresh out of high school, my office was a stretch of flightline in Florida that contained a fleet of three squadrons of F-15s, where we trained pilots to go out and perform the tasks of war and maintain the United States' superiority in combat airspace. What an amazing responsibility and privilege.

The sun is setting on the F-15 C/D mission as fifth-generation fighters take on that role. My jet, 83-0015, is in the boneyard after a student pilot drove it through a flightline light pole, but some of this fleet are still prowling the skies with a handful of units, and even foreign nations.

The F-15E Strike Eagle continues to dominate in its arena and will do so for the foreseeable future. Over 40 years since its initial design, the F-15 remains one of the greatest fighter aircraft of all time, with performance records that still stand, an unmatched air-to-air record and a legendary status. None of this would be possible without the knuckledraggers working day in and day out on the flightline. As a 'nonner' – someone who doesn't work the flightline – I'm proud to have at one time been a knuckledragger myself, and to have contributed to the success of the F-15 Eagle.

# Appendix 1

## United States Air Force Eagle and Strike Eagle units (April 2014)

### F-15A/B/C/D Eagle

**18th Wing, F-15C/D, Kadena AB, Japan**
44th FS Vampires.
67th FS Fighting Cocks.

**46th Test Wing, F-15A/B/C/D, Eglin AFB, Florida**
40th FLTS Fightin' Red Devils.
586th FLTS Roadrunners – conducts tests with one F-15A at Holloman AFB, New Mexico.

**48th Fighter Wing, F-15C/D, RAF Lakenheath, England**
493rd FS Grim Reapers.

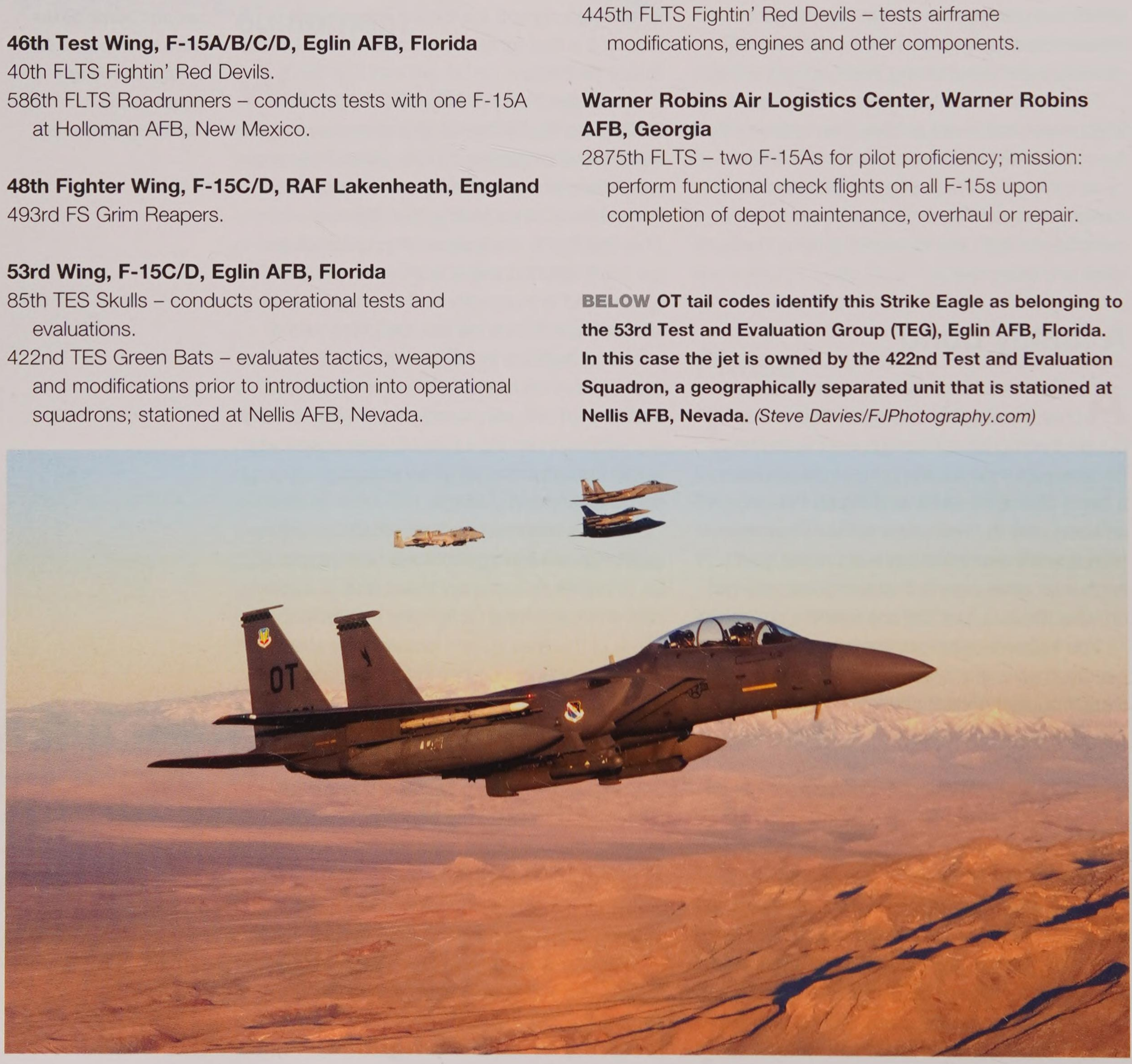
**53rd Wing, F-15C/D, Eglin AFB, Florida**
85th TES Skulls – conducts operational tests and evaluations.
422nd TES Green Bats – evaluates tactics, weapons and modifications prior to introduction into operational squadrons; stationed at Nellis AFB, Nevada.

**57th Wing, F-15C/D, Nellis AFB, Nevada**
433rd FWS Satan's Angels – F-15 Fighter Weapons School.

**412th Test Wing, F-15A/B/C/D, Edwards AFB, California**
445th FLTS Fightin' Red Devils – tests airframe modifications, engines and other components.

**Warner Robins Air Logistics Center, Warner Robins AFB, Georgia**
2875th FLTS – two F-15As for pilot proficiency; mission: perform functional check flights on all F-15s upon completion of depot maintenance, overhaul or repair.

**BELOW OT tail codes identify this Strike Eagle as belonging to the 53rd Test and Evaluation Group (TEG), Eglin AFB, Florida. In this case the jet is owned by the 422nd Test and Evaluation Squadron, a geographically separated unit that is stationed at Nellis AFB, Nevada.** *(Steve Davies/FJPhotography.com)*



**Air National Guard**

102nd FW Massachusetts ANG; 131st FS, F-15A/B, Barnes Municipal Airport, Massachusetts.

120th FW Montana ANG; 186th FS, F-15C/D, Great Falls International Airport, Missouri.

125th FW Florida ANG; 159th FS, F-15C/D, Jacksonville International Airport, Florida.

142nd FW Oregon ANG; 123rd FS, F-15C/D, Portland International Airport, Oregon.

154th Wing Hawaii ANG; 199th FS, F-15C/D, Hickam AFB, Hawaii.

159th FW Louisiana ANG; 122nd FS, F-15C/D, NAS New Orleans, Louisiana.

173rd FW Oregon ANG; 114th FS, F-15C/D, Klamath Falls International Airport, Oregon.

**RIGHT Two 493rd FS 'Grim Reapers Eagles split during air combat training over the North Sea. Stationed at RAF Lakenheath, the Eagles have become a familiar sight over the skies of East Anglia.** *(Steve Davies/FJPhotography.com)*

**BELOW The SJ tail codes mark these F-15Es as 4th FW aircraft from Seymour Johnson AFB, North Carolina. The base is home to four active duty Strike Eagle squadrons and one reserve squadron.** *(Steve Davies/FJPhotography.com)*

**ABOVE With distinctive orange and black tiger-stripe fin flashes, the Strike Eagles of the 'Bold Tigers' – the 391st FW, 366th Wing, Mountain Home AFB, Idaho – are easily recognised.** *(Steve Davies/FJPhotography.com)*

## F-15E Strike Eagle

**4th Fighter Wing, Seymour Johnson AFB, North Carolina**
333rd Fighter Squadron.
334th Fighter Squadron.
335th Fighter Squadron.
336th Fighter Squadron.

**53rd Wing, Eglin AFB, Florida**
85th Test and Evaluation Squadron.

**53rd Wing, Nellis AFB, Nevada**
422nd Test and Evaluation Squadron, Nellis AFB, Nevada.

**57th Wing, Nellis AFB, Nevada**
17th Weapons Squadron.

**366th Fighter Wing, Mountain Home AFB, Idaho**
389th Fighter Squadron.
391st Fighter Squadron.
428th Fighter Squadron – mixed USAF/RSAF unit for training Republic of Singapore Air Force crews on the F-15SG.

**48th Fighter Wing, RAF Lakenheath, England**
492nd Fighter Squadron.
494th Fighter Squadron.

**46th Test Wing, Eglin AFB, Florida**
40th Flight Test Squadron.

**412th Test Wing, Edwards AFB, California**
415th Flight Test Squadron.
419th Flight Test Squadron.

## United States Air Force Reserve

**414th Fighter Group, Seymour Johnson AFB, North Carolina**
307th Fighter Squadron.

**ABOVE** The ZZ tail codes are from Kadena AB, Japan, where the 44th and 67th Fighter Squadrons of the 18th Wing reside. *(USAF)*

**BELOW** Pilot and WSO walk to their jet with the yellow flashes of the 336th FS behind them. Known colloquially as the 'World Famous Flying Fighting F***ing Rocketeers', the 'Rocketeers' (as they are more publicly known) are another of the 4th FW's Strike Eagle units at Seymour Johnson AFB. *(Steve Davies/ FJPhotography.com)*

**BELOW** Black band with a yellow outline denotes the 493rd FS at Lakenheath. *(USAF)*

**ABOVE** **The 335th FS 'Chiefs' flagship on the ramp at Seymour Johnson AFB, North Carolina.** *(Steve Davies/ FJPhotography.com)*

**RIGHT** **AK for Alaska – two 19th FS Eagles penetrate the weather in formation, hoping to break out into clear blue skies. The 19th FS was eventually inactivated, and Alaskan Eagles are no more.** *(USAF)*

# Appendix 2

## Acronyms

**A/A** Air-to-air.
**AAA** Anti-aircraft artillery.
**AAR** Air-to-air refuelling.
**AB** Air Base; also afterburner.
**ACMI** Air combat manoeuvring instrumentation.
**ACTIVE** Advanced Control Technology for Integrated Vehicles.
**ADCC** Assistant Dedicated Crew Chief.
**ADECS** Advanced DEEC engine control system.
**ADP** Air data processors.
**AEF** Air Expeditionary Forces.
**AESA** Active electronically-scanned array.
**AF** Air Force.
**AFB** Air Force Base.
**AFC** Afterburner fuel control.
**AFCS** Automatic flight control system.
**AFDT&E** Air Force Development Test & Evaluation.
**AFSC** Air Force Systems Command.
**A/G** Air-to-ground.
**AGE** Aerospace ground equipment.
**AIU** Avionics interface unit.
**AMAD** Airframe-mounted accessories drive, or auxiliary mounted airframe device.
**AMARC** Aviation Maintenance and Regeneration Center.
**AMRAAM** Advanced medium-range air-to-air missile.
**ANG** Air National Guard.
**ANGB** Air National Guard Base.
**AOA** Angle of attack. The angle of the wing as it cuts through relative airflow.
**ARI** Aileron rudder interconnect.
**ASAT** Anti-satellite missile.
**ASE** Allowable steering error.
**ASP** Avionics status panel.
**ATDPS** Asymmetric thrust departure prevention system.
**ATEGG** Advanced Turbine Engine Gas Generator.
**ATO** Air Tasking Order.
**BFM** Basic fighter manoeuvre.
**BIT** Built-in test.
**BRA** Bearing-range-altitude.
**BRU** Bomb release unit.
**BST** Boresight.
**BVR** Beyond visual range.
**C3** Command, control and communications.
**CALCM** Conventional air-launched cruise missile.
**CAOC** Combined Air Operations Center.
**CAP** Combat air patrol.
**CAS** Control augmentation system.
**CC** Central computer.
**CDT&E** Contractor Development Test & Evaluation.
**CFT** Conformal fuel tank.
**CGB** Central gear box.
**CIVV** Compressor inlet variable vane.
**CMD** Counter munitions dispenser.
**CSAF** Chief of Staff of the Air Force.
**CSBPC** Control stick boost/pitch compensator.
**DACT** Dissimilar air combat training.
**DCC** Dedicated Crew Chief.
**DCP** Development Concept Paper.
**DEEC** Digital electronic engine control.
**DEL** Direct electronic link.
**DoD** Department of Defense.
**DTM** Digital data transfer module.
**DTT** Dual Target Track.
**DVR** Digital video recorder.
**E&E** Escape and evasion.
**ECS** Environmental control system.
**EDU** Engine diagnostic unit.
**EEC** Engine electronic control.
**EGI** Embedded GPS inertial navigation system.
**EGSSV** Emergency generator selector switch valve.
**ELINT** Electronic intelligence.
**EM** Energy Manoeuvring.
**EOR** End of runway.
**EPR** Engine pressure ratio.
**FAC** Forward air controller.

**FCC** Flight control computer.
**FDL** Fighter Data Link.
**FIG** Fighter-Interceptor Group.
**FIS** Fighter-Interceptor Squadron.
**FL** Flight level.
**FLIR** Forward-looking infrared.
**FOD** Foreign object damage.
**FOT&E** Follow-on Operational Test & Evaluation.
**FS** Fighter Squadron.
**FTF** Flight Test Fixture.
**FTIT** Fan turbine inlet temperature.
**FW** Fighter Wing.
**FWS** Fighter Weapons School.
**FWW** Fighter Weapons Wing.
**F-X** Fighter – Unknown number designation (*not* 'Fighter Experimental').
**g** Measure of gravitational force.
**GD** General Dynamics.
**GE** General Electric.
**GIT** Ground idle thrust.
**GLOC** g-induced loss of consciousness.
**GM** General Motors.
**GPS** Global positioning system.
**HAS** Hardened aircraft shelter.
**HIDEC** Highly integrated digital electronic control.
**HOBS** High off-bore sight.
**HOTAS** Hands-on throttle and stick.
**HPRF** High pulse repetition frequency.
**HRM** High resolution maps.
**HSI** Horizontal situation indicator.
**HUD** Heads-up display.
**HYD** Hydraulic.
**IADS** Integrated air defence system.
**ICS** Internal countermeasures set.
**ICSCP** Intercommunications set control panel.
**IDEEC** Improved digital electronic engine control.
**IDG** Integrated generator.
**IFF** Identification friend or foe.
**IGMT** Interleaved ground moving target.
**ILS** Instrument landing system.
**INS** Inertial navigation system.
**IP** Initial point.
**IR** Infrared.
**JASDF** Japan Air Self-Defence Force.
**JDAM** Joint direct attack munition.
**JEPO** Joint Engine Project Office.
**JHMCS** Joint helmet-mounted cueing system.
**JFS** Jet fuel starter.
**KCAS** Calibrated airspeed.
**KIAS** Knots indicated air speed.
**kt** Knots.
**LANTIRN** Low-altitude navigation, terrain-following infra-red for night.
**LDGP** Low-drag general purpose.
**LGB** Laser-guided bomb.
**LITENING** AAQ-28 target pod.
**LOD** Light-off detector.
**LRS** Long-range search.
**LRU** Line replaceable unit.
**MANPADS** Man-portable air defence systems.
**McAir** Nickname of the aircraft company division of McDonnell Douglas.
**MFC** Main fuel control.
**MiG** Soviet aircraft designed by the Mikoyan-Gurevich bureau.
**MIL** Military power – maximum power without use of reheat/afterburner.
**MOGAR** Missouri Air National Guard.
**MPCD** Multi-purpose colour display.
**MPD** Multi-purpose display.
**MPDP** Multi-purpose display processor.
**MPRF** Medium pulse repetition frequency.
**MRM** Medium-range missile.
**MSIP** Multi-Stage Improvement Program.
**MSL** Mean sea level.
**MUX** H009 multiplex bus.
**NATO** North Atlantic Treaty Organisation.
**NGS** Nose gear steering.
**nm** Nautical miles.
**NORAD** North American Aerospace Defense Command.
**NTISR** Non-traditional information surveillance and reconnaissance.
**NVN** North Vietnam.
**NWS** Nose wheel steering.
**OAF** Operation Allied Force.
**OCA** Offensive counter air sortie.
**ODS** Operation Desert Storm.
**OEF** Operation Enduring Freedom.
**OFP** Operational flight program.
**OIF** Operation Iraqi Freedom.
**ONA** Operation Noble Anvil.
**ONE** Operation Noble Eagle.
**ONW** Operation Northern Watch.
**OOD** Operation Odyssey Dawn.
**OPC** Operation Provide Comfort.
**OSW** Operation Southern Watch.
**OWS** Overload warning system.
**PACAF** Pacific Air Command.

**P&W** Pratt & Whitney.
**PC** Power Control.
**PD** Pulse-Doppler.
**PID** Positive identification.
**PRF** Pulse repetition frequency.
**PRI** Primary engine control.
**PSAB** Prince Sultan Air Base, Saudi Arabia.
**psi** Pounds per square inch.
**PSP** Programmable signal processor.
**PTC** Pitch trim controller.
**PTM** Practice training missile.
**PTO** Power take-off.
**R&R** Removing and re-installing.
**RBF** Remove before flight.
**RCVV** Rear compressor variable vane.
**RFP** Request for proposal.
**RICP** Remote intercommunications control panel.
**RLS** Reservoir level sensing.
**RMP** Radar Modernisation Program.
**RO** Response option.
**ROE** Rules of engagement.
**rpm** Revolutions per minute.
**RTB** Return to base.
**RWR** Radar warning receiver; pronounced 'raw'.
**SA** Situational awareness.
**SAC** Strategic Air Command.
**SAM** Surface-to-air missile.
**SAR** Semi-active radar or synthetic aperture radar.
**SEAD** Suppression of enemy air defences.
**SEAWARS** Seawater-activated release system.
**SEC** Secondary engine control.
**SECAF** Secretary of the Air Force.
**S/MTD** Short Take-Off and Landing/ Maneuvering Technology Demonstrator.
**SRFCS** Self-repairing flight control system.
**SRAM** Short-range attack missile.
**SRM** Short-range missile.
**SRS** Short-range search.
**SS** Super Search.
**STT** Single Target Track.
**TAC** Tactical Air Command.
**TACC** Tactical Air Control Centre.
**TACAN** Tactical air navigation system.
**TAF** Tactical Air Forces.
**TD** Target designator.
**TDC** Target designator control.
**TF** Terrain-following.
**TEG** Test and Evaluation Group.
**TEWS** Tactical electronic warfare suite.
**TFS** Tactical fighter squadron.
**TFTS** Tactical fighter training squadron.
**TFTW** Tactical fighter training wing.
**TFW** Tactical fighter wing.
**TIC** Troops in Contact.
**TO** Technical Order.
**TP** Target Pod.
**TR** Transformer-rectifier.
**TR(s)** Training rule(s).
**TST** Time Sensitive Tasking.
**TTW** Tactical training wing.
**TWS** Track-while-scan.
**UFC** Upfront control panel.
**USAF** United States Air Force.
**USAFE** United States Air Forces in Europe.
**USN** United States Navy.
**USSR** Union of Soviet Socialist Republics.
**UTL** Utility.
**VG** Variable geometry.
**VID or VI** Visual identification.
**VS** Vertical scan.
**VSD** Vertical situation display or 'radar scope'.
**WEZ** Weapons employment zone.
**WFOV** Wide field of view.
**WSO** Weapons systems officer.

**BELOW Still wearing the Gulf Spirit logo that it returned with following Operation Desert Storm, the 33rd FW flagship marks its final days at Eglin AFB, Florida, looking pristine. The Wing has since transitioned to the F-35 Lightning II Joint Strike Fighter. Note the Iraqi Air Force MiG kills on the side of the jet.** *(Steve Davies/ FJPhotography.com)*

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# McDONNELL DOUGLAS/BOEING F-15 EAGLE

## 1972 onwards (all marks)

ABOVE **The 58th Tactical Fighter Squadron would end the First Gulf War as the leading MiG-killer unit. Stationed at Eglin AFB, Florida, the 'Gorillas' took a mix of MSIP and non-MSIP jets to operation Desert Shield, but by the time the war began on 17 January 1991 its non-MSIP jets had all been swapped out.** *(Steve Davies/FJPhotography.com)*

LEFT **The 1st Tactical Fighter Wing deployed to Prince Sultan AB, Saudi Arabia, on 7 August 1990, spearheading the entire coalition airpower force. This 71st TFS D-model sits outside one of PSAB's shelters, armed with four live AIM-9L Sidewinders and four AIM-7M Sparrows. The two-seat 'tub' jets were not used in combat, but were relied upon for local area familiarisation and continuation training sorties.** *(USAF)*

### The First Gulf War

When Iraq's dictator, Saddam Hussein, invaded neighbouring Kuwait in August 1990, the United States and its coalition allies sprang into action. The West's response came in two phases: a defensive operation – Desert Shield – designed primarily to thwart any attempt by Hussein's forces to roll south into Saudi Arabia, and an offensive operation – Desert Storm – to repel the occupying Iraqi forces from Kuwait.

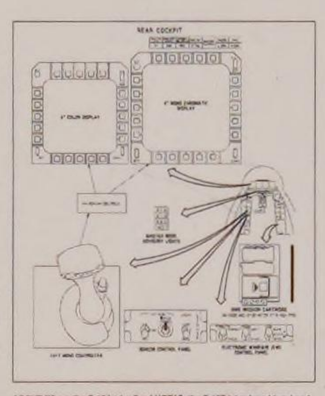


Operation Desert Shield began with the deployment of F-15Cs and F-15Es to the Persian Gulf region. The 1st FW at Langley AFB sent 24 F-15C and 3 F-15D aircraft to Dhahran AB, Saudi Arabia, on 7 August. The next day, 25 F-15C/Ds arrived from the 27th TFS. The Eagles immediately began flying combat air patrols to protect Saudi Arabia's sovereign air space. The Eagles were the first coalition tactical air assets to arrive in theatre.

On 9 August the 336th TFS's F-15Es arrived at Thumrait AB, Oman, via Dhahran, Saudi Arabia. At this time, of course, the Strike Eagle was still so new that it was cleared to release only the 2,000lb Mk 84 and 500lb Mk 82 LDGP (low-drag general purpose) bombs, making it what amounted to little more than a very sophisticated dumb bomb truck. Nonetheless, the Strike Eagles were the coalition's only real strike capability in theatre at this critical time – the only credible strike capability that could slow (but, it was accepted, not halt) an Iraqi ground assault into Saudi. As it turned out, the threat of further advances by Iraqi ground forces passed and the Rocketeers and 335th TFS Chiefs (who had by now joined the Rocketeers) moved to Al Kharj AB, Saudi Arabia, in December.

USAF Europe's growing commitment to the build-up continued, with the 53rd TFS, 36th TFW, sent 24 MSIP II F-15Cs from Bitburg Air Base, Germany, deploying to Prince Sultan AB, Saudi Arabia, on 20 December. Meanwhile, sister squadron the 525th TFS deployed to Incirlik AB, Turkey, to patrol Iraq's northern territories. Additional F-15Cs from the 32nd TFS, Soesterberg AB, the Netherlands, later joined the Turkish-based 525th TFS, arriving on the first day of the war – 17 January 1991.

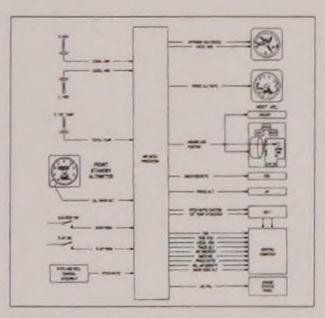
In Riyadh, Saudi Arabia, coalition representatives and the US had formed the Tactical Air Control Centre (TACC) to plan the air war. The TACC published the 600-page Air Tasking Order (ATO) – the route map for the air



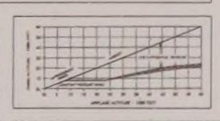
ABOVE **Where the F-15 had refined HOTAS, the F-15E introduced two hand controllers for the WSO, enabling him or her to access almost all of the jet's attack capabilities without ever having to remove their hands. The WSO also uses the controllers to scroll through 'pages' on their multi-purpose displays and multi-purpose colour displays.** *(USAF)*

RIGHT **Captain Rick 'Kluso' Tollini plays a Game Boy to unwind between sorties. Kluso planned the 33rd TFW's participation in the air war, and would claim a MiG-25 Foxbat in one of the Eagle's most exhilarating combat actions later in the war.** *(Rick Tollini via Steve Davies)*

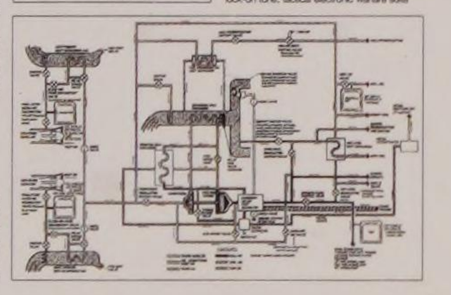




ABOVE **The air data system takes inputs from a range of other subsystems and sensors in order to provide flight information to the pilot.** *(USAF)*



CENTRE **The Eagle and Strike Eagle cockpits are pressurised to a fixed schedule.** *(USAF)*



RIGHT **The ECS (environmental control system) takes engine bypass air and uses it to cool or heat aircraft systems, as required.** *(USAF)*

is retained with the loss of any or all mechanical linkages. The three-channel design turns any axis off when a second like failure occurs.

The CAS affects stabilator and rudder position only; the ailerons are not controlled by the CAS. A moderate yaw transient may occur and is normal when yaw CAS is disengaged, re-engaged, or the landing gear is lowered. The DEL mode is activated when a spin mode is detected and the CAS is disengaged. DEL provides a direct electrical interconnect from the lateral stick to the stabilator actuators, which enables the pilot to command differential stabilator for spin recovery.

#### Autopilot modes

In the pitch axis, autopilot provides attitude control, barometric or radar altitude hold, barometric or radar altitude select, and the attitude hold or altitude select functions of blended autopilot/terrain-following (blended mode). In the roll axis, autopilot provides attitude hold, heading hold, TACAN (tactical air navigation system) steering, navigation steering or ground track steering.

#### Audio warning system

The audio warning system is made up of both audio tones and voice warnings. The weapons lock-on tone, tactical electronic warfare suite (TEWS) caution and launch tones, instrument landing system (ILS) audio, and TACAN audio are volume-controlled by the remote intercommunications control panel (RICP) for the front cockpit and the intercommunications set control panel (ICSCP) for the rear cockpit.

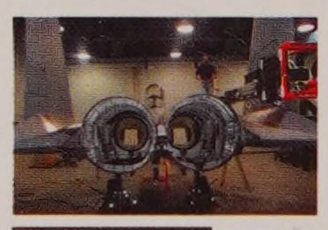
The overload warning system (OWS) tone is generated by the multi-purpose display processor (MPDP) when the aircraft approaches design limit structural overload. When overload is exceeded, the tone is replaced with a voice warning. The unsafe landing warning tone is generated as a function of landing gear position, aircraft attitude, airspeed and rate of descent.

#### Boarding steps

A boarding steps position indicator on the left canted bulkhead will display 'UP' when the steps are retracted and 'DOWN' when the steps are extended. The retractable boarding steps are released by pressing one of two release buttons. One release button is located inside the top kick-in step and another release button is located on the retractable step door. Pressing either button allows the steps to freefall to the down position.

#### Canopy system

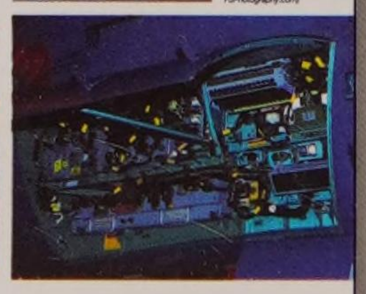
The cockpit area is enclosed by a clamshell-type canopy and an impact-resistant



ABOVE **A look through the fuselage with engines removed.** *(USAF)*

LEFT **Beneath these covers lie the connections that bolt the F100 engines into the Eagle. Located on the upper fuselage, each engine is connected by only two sets of the attachment points.** *(Steve Davies/FJPhotography.com)*

BELOW AND RIGHT **Avionics bays house multiple 'black boxes', more formally known as line replaceable units. When one breaks, the crew chief or specialist can simply remove it and replace it with another.** *(Steve Davies/FJPhotography.com)*





The Boeing (formerly McDonnell Douglas) F-15 all-weather tactical jet fighter is statistically the most successful fighter jet ever built, with 105 kills for zero losses. Big and fast, with a very useful combat range, the aircraft is also undeniably beautiful.

The F-15 Eagle was the result of a US requirement for a fighter design to counteract the cold war threat of the Soviet MiG-25 Foxbat which was unveiled in 1967. The requirement was for a high-performance fighter optimised to engage and kill its adversaries while still beyond visual range, and once they closed to within the 'visual arena' to be able to outmanoeuvre the enemy to gain a shooting advantage.

The prototype first flew in June 1972, and the first production F-15 was delivered to the USAF in November 1974. The Eagle entered service in 1976, and is expected to remain in service until 2025. Both single- and two-seat variants were produced. From its outset, the F-15 had been developed to carry both air-to-air missiles and some 15,000lb of bombs, but McDonnell Douglas saw an opportunity for a dedicated two-seat strike version as a replacement for the USAF's ageing F-111 fleet, leading to the F-15E Strike Eagle, which made its maiden flight in 1985, and entered frontline service in 1988.

The Eagle and Strike Eagle have flown combat operations in a number of theatres with the USAF, Israeli Air Force and Royal Saudi Air Force, serving with distinction with the USAF in both Gulf Wars, the Balkans, Afghanistan, and most recently Libya in 2011.

This manual provides a unique insight into the design, evolution, operation and maintenance of the USAF's all-weather tactical fighter jet. With the aid of information from official technical publications in the public domain, along with narratives from pilots and maintainers, the fascinating text, supported by numerous technical illustrations and photographs, describes in detail how the F-15 is built, employed as a weapons system, and maintained.

**Steve Davies** is a freelance military aviation photojournalist and author. This is his fourth Haynes Owners' Workshop Manual. He is the author of more than a dozen other critically acclaimed books, and he has worked as an adviser for a range of military aviation documentaries in the UK and US. His photography has been used by the aviation press and leading defence contractors and aviation corporations.

**Doug 'Disco' Dildy** is a retired US Air Force F-15C pilot, with 1,400 Eagle hours in his log book. With 26 years service in the USAF, his last position was Vice Wing Commander of the 33rd Fighter Wing at Eglin AFB, Florida. Currently a commercial pilot, he is also an accomplished author, having written a number of books about military campaigns and aircraft.

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